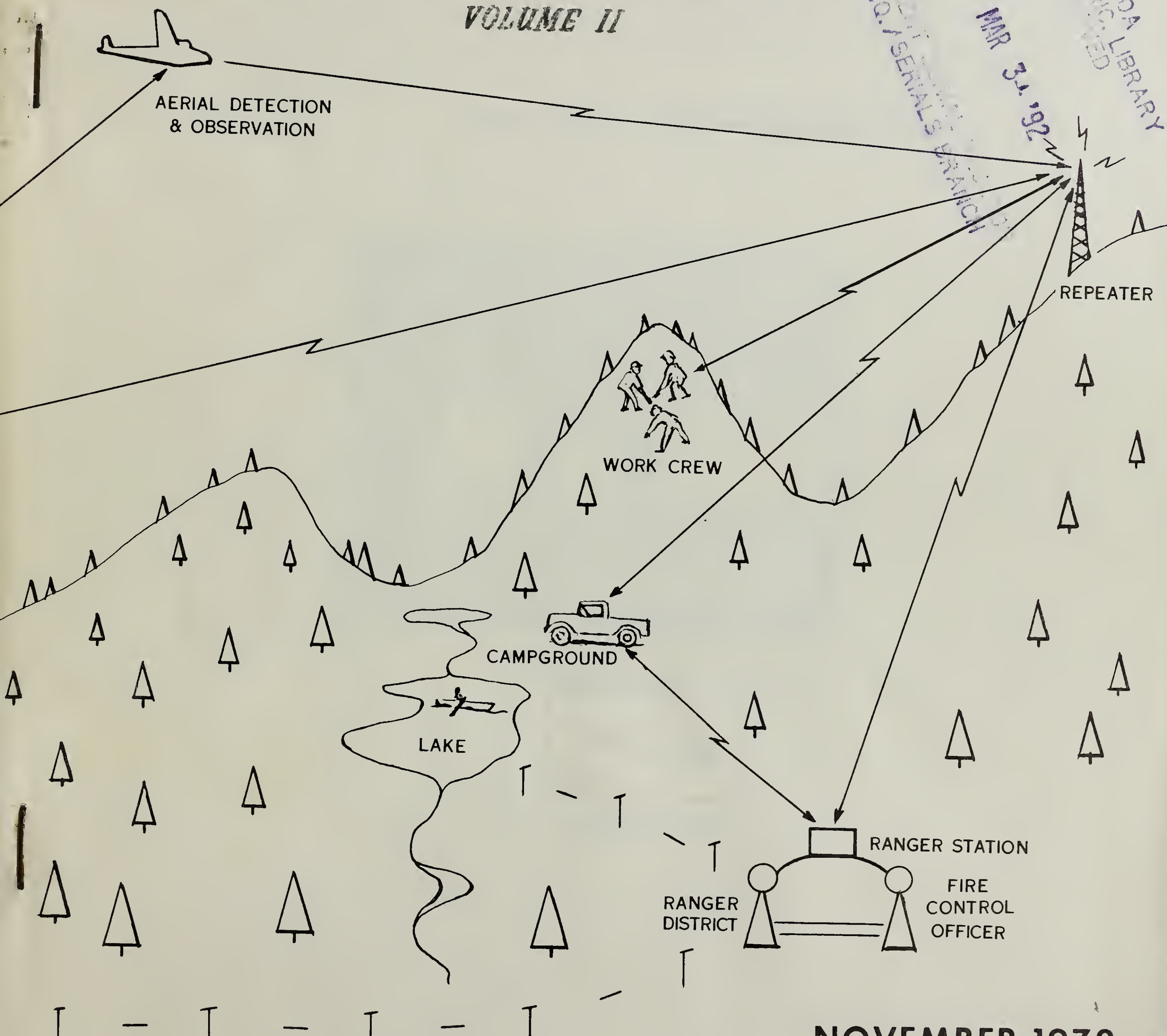
Requirements, Replacement + Maintenance

A STUDY OF
FOREST SERVICE TELECOMMUNICATIONS

VOLUME II



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FOREST SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE TELECOMMUNICATIONS STUDY

VOLUME II

Requirements Evaluation

Replacement and Maintenance Policies

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

TABLES

page

EXHIBITS

INTRODUCTION

A. STUDY OBJECTIVES

The study attempts to provide a rational foundation for the management of the Forest Service communication systems. Up to this point, no systematic evaluation of the contributions of the Forest Service radio systems has been attempted. The study shows that such an evaluation is practicable. A first sample evaluation of the contributions of radios shows these to be commensurate with system costs. The procedures recommended for the evaluation of communication requirements are based on the experiences gained in the sample evaluation of the contributions of the present radio system to Forest Service management objectives.

Present radio replacement and maintenance policies are carefully analyzed and recommendations for changes are provided. The replacement of obsolete radio equipment has historically been an unresolved Forest Service problem.

The extent of the problem is indicated by the age of equipment reported in the study questionnaire. Regional offices report average ages of between 8 and 21 years with an overall average age of 14.2 years. There are no specific replacement standards in the Forest Service's 7200 Communications and Electronics Manual.

The Communications Task Force of 1968 also identified obsolete equipment and the lack of a replacement policy as a problem of communications management.

No agreement exists at present among Forest Service electronics engineers about the required frequency of preventive maintenance. Questionnaire responses range from one time per year to four times per year. The Radio Technician's Handbook, FSH-7200, gives standards of four times per year for equipment used year-round or every 3 months of use for equipment used intermittently.

In interviews conducted during the study with public and private agencies, no agreement could be obtained on a appropriate preventive maintenance schedule. Actual practices showed schedules with a range of no preventive maintenance to once every month of use. Moreover, it was found that there appeared to be no relationship between existing preventive maintenance schedules and the observed equipment failure rates.

It has been clear for some time that the standards (as set forth in the Radio Technician's Handbook) cannot be met with present manpower and money constraints. Moreover, Forest Service Electronics Engineers pointed out at the Regional Electronics Engineers meeting in Denver, October, 1968, that these standards were no longer realistic or supportable for present day equipment.

This study attempts to provide the methodologies, procedures and policies required to resolve these and related problems of Forest Service communication management.

STUDY PARTICIPANTS

Study participants are listed in Volume I.

Special thanks are due to the many questionnaire respondents for the special effort necessary to provide the data basis for this study. Members of the Electronics and Communications Branches in all Regions have especially contributed in this way and have additionally provided valuable consultation on many phases of the study.

B. NEW TECHNOLOGY--BASIS FOR FUTURE TELECOM REQUIREMENTS

New technology provides continuous improvements in telecommunication techniques, thus making frequently new methods of management possible. The use of new hardware in previous applications can become so much more advantageous that a change-over becomes necessary. We review briefly some developments which may have this impact in the field of telecommunications in the near future.

MULTI-CHANNEL RADIOS

Multichannel radio equipment has already arrived and is here to stay. Frequency modulated all-channel radios have been developed. Standard crystal controlled personal portable radios with up to 5 channels can now be purchased at a reasonable cost. All-channel portable equipment has not yet been developed for field use, but should be available in the near future. Aircraft and mobile all-channel equipment is now available, but at a premium price. These prices should come down when the all-channel radio proves to be widely needed.

MINIATURIZATION

Miniaturized radio equipment has made great strides in recent years. Weights have declined from 10 to 12 pounds to 12 to 14 ounces. Bulk has similarly been reduced. Further portable miniaturization probably cannot be expected because they are already so samll that further miniaturization would have diminishing advantages. However, we can expect more and more features such as multiple channels, selective calling, tone alerts, and others to be incorporated without increase in size. Base station and mobile radios will probably be further miniaturized.

TELEPHONE SERVICE

A recent decision by the FCC has made legal a device that can be used to patch the Forest radio network into the normal telephone system. We should see more and more use of this feature in Forest or Regional radio systems. An increased use of radio telephone services may also be expected with the increasing availability of such services.

Telephone service and use is destined to change dramatically in the future. The General Service Administration (GSA) estimates a 12% growth in voice communication and a 26% growth in data communications over the FTS networks in Fiscal Year 1972. Memos may become a thing of the past, as hard copy

transmission over telephone circuits increase. Increased data transmissions could also be facilitated in the future by picturephones. Intercom lines from Regional offices to supervisors' offices and to district offices may well be feasible in the near future. A steady growth in conference calls may also be expected.

DATA TRANSMISSION

Data transmission, both radio and telephone, should undergo the most dramatic growth in the coming years. Quality resource management decisions, in this day of rapid communications and immediate impacts, require pertinent, real time data. Data collection and transmission technology is progressing at such a rate that soon remote field data may become available for use by the manager almost immediately. Bookkeeping, financial records, and other management chores could be handled automatically and centrally with long distance data transmission facilities.

SATELLITES

Earth communications satellites are a recent communications technology advance which holds future promise for the Forest Service. The primary objective of communications satellites is point to point, long range information exchange at tremendous volumes. The cost to build and launch such a satellite is prohibitive in the foreseeable future. Agency cooperation, as in the Earth Resources Satellite, may bring general satellite communications sooner. It is conceivable that a complete Service-wide communications system with proper network isolation could be designed with the use of satellites, but it is some distance in the future.

There are other, more modest, new technologies that make management more effective and work more efficient; some examples are:

PAGING SYSTEMS

Systems are available that could be used in conjunction with a new or existing forest radio system that would allow selective calling and paging in the system. Other devices that are less expensive would allow people with the device to be notified that they are wanted and should call a pre-arranged number or location. The utility of these devices should be considered by the communications manager.

AUTOMATIC VEHICLE LOCATORS

These devices may find application in Forest Service vehicles in the future. Possible applications are in law enforcement, fire suppression, or camp ground management. The device indicates the location of a vehicle, with the device installed, on a locator board or map back at headquarters. For the time being, these systems are not practicable outside metropolitan areas.

SECURITY TECHNIQUES

Some of the security techniques are message scrambles or special alarm switches for radios. There are intrusion devices available. All these may well be needed for forest managers of the future.

EXOTIC POWER TECHNIQUES

New technology in power generating devices has made great strides in the last few years. The Forest Service may make use of such things as thermoelectric generators, small nuclear reactors, or fuel cells in the future. Thermoelectric devices are already used extensively in the Forest Service to power remote radio stations.

C. STUDY DATA SOURCES

Most of the results of this study are based on information supplied by respondents in regional, supervisory and district offices.

1. Regional questionnaire. This was a two part questionnaire--one part for regional Electronics Engineers and one for the regional Division of Operations. The engineers' section covered technical aspects of the regions' communications program, while the operations part concerned itself with present and planned investments in communication equipment. All regions except Alaska were asked to complete this questionnaire (Appendices B1 and B2, pages A20 and A25).

2. Forest Supervisor questionnaire. This two part questionnaire was sent to a sample of 33 of the national forests (Appendix B3, page A31). Part one of the questionnaire concerned management and operations while part two concerned technical aspects of the forest radio system and its maintenance (Appendices B4 and B5, pages A33 and A39).

3. District Ranger questionnaire. Two rangers on heavy workload districts on the sample forests replied to this questionnaire which was aimed at exploring the use and benefits of the present communication systems and on exploring needed improvements (Appendix B6, page A41).

4. District Staff questionnaire. Up to five people on the ranger's staff on each of the selected districts were asked to reply to this questionnaire. It was similar to the ranger's but limited to describing needs and benefits associated with the respondent's specialty (Appendix B7, page A60).

Forests were selected regionally as follows:

- 5 forests in Regions 4 and 6
- 4 forests each in Regions 1, 2, 5, 8 and 9
- 3 forests in Region 3

Response to the questionnaires was excellent. All regions, 30 supervisors offices (out of 33 possible), and 63 districts responded with completed questionnaires. Altogether, 276 replies were received to the ranger and district staff questionnaires.

All regions, except Alaska, were involved in subsequent data collection and verification interviews. These were carried out by two-man parties of study team members accompanied by regional representatives. Interviews were conducted with forest and district personnel. These discussions were aimed at verification and further exploration of tentative conclusions.

Field Contacts

Region 1 - Post-questionnaire: seeking confirmation of questionnaire results and discussions of organization alternatives. Visits on one Ranger District and Regional Office Staff.

Region 2 - Post-questionnaire: discussions on questionnaire results at four Ranger Districts (1 National Grassland, 3 National Forests) 2 Supervisors Offices and Regional Office.

Region 3 - Pre-questionnaire: exploring questions on staffing policy and plans with Regional Communications Engineer and concerned Regional Office Staff.

Region 4 - Pre-questionnaire: discussions with Regional Communications Committee and other Regional Office Staff on workloads, financing, record keeping and forest investment records. Visit to one National Forest.
Post-questionnaire: joined by Division of Operations in discussion of organizational proposals.

Region 5 - Pre-questionnaire: pretest general questionnaire with district and forest personnel on one National Forest. Discussions with Regional Communications Engineer and Division of Operation on financing and planning.

Region 6 - Post-questionnaire: verification of tentative conclusions,especially in regard to search and rescue operations. Two Ranger Districts and two National Forests.

Region 8 - Pre-questionnaire: discussions with operations, engineering and fire control on cost-benefit evaluation, staffing,financing and organizing. Regional Office, two Forests, two Ranger Districts.

Region 9 - Post-questionnaire; accompanied by Regional Communications Engineer, visits with forest and district personnel on two Ranger Districts. Confirmation of functional requirements in fire and recreation. Status of maintenance record keeping.

Supplemental Maintenance and Replacement Evaluation Data Collection

Complete forest radio inventories were obtained for all regions. Following this, a sample of 69 forests was selected to furnish a complete maintenance history of its communication equipment. Histories were obtained on 520 pieces of equipment (Appendix B8, page A74). At the same time, sample forests also furnished data for technician travel expenses and cost of replacement parts. This information was used in developing the maintenance and replacement recommendations detailed later.

Expert opinion about preventive maintenance schedules was obtained in interviews with several public and private agencies, and from the general questionnaire.

PART I

SUMMARY OF FINDINGS,

RECOMMENDATIONS, AND

EVALUATION PROCEDURES

A. SUMMARY OF FINDINGS

1. For the non-random sample of 63 districts studied, the average yearly ownership cost of the district radio communications system, amortized over ten years, was $6,850. Regional averages varied from $3,900 in Regions 2 and 9 to $11,300 in Region 5.

2. The reported average yearly benefit associated with the use of a radio telecommunication system was $9,750 per district. The average yearly net benefit (benefit minus cost) from radio communications was $2,900 per sample district. (Sample districts were mostly in the average and above average workload category.)

3. All regions showed a positive net benefit associated with the sample radio communication systems. Three regions showed an average net yearly benefit of $4,500 or more per sample district.

4. The average annual return on the capital invested in the sample district radio communication system was 24 percent.

5. The average benefit attributable to non-emergency use (excluding fire and safety) of radio communication systems was $4,580 per year per district. This amounted to 47% of the total average benefit per sample district. Benefits associated with fire pre-suppression uses of the radio systems contributed 39% of the tabulated benefits. Safety uses accounted for 14% of the tabulated benefits.

6. Rental of radio equipment without maintenance for a minimum of three years would be at present twice as expensive on the average as Forest Service ownership of the same equipment. Rental for a period less than three years would significantly increase the ratio in favor of Forest Service ownership.

7. Rental of radio equipment with maintenance would still favor Forest Service ownership for an average gain of 37% per year. Additionally, rental with maintenance would (a) very significantly increase the equipment unavailability ratio, and (b) provide no emergency field service nor adequate technician services for fires.

8. Amortized over ten years at 7%, capital costs for communication system components ranged from \$48/yr. for a remote control console to \$519/yr. for a battery powered repeater. Average total ownership costs per year ranged from \$99 for a remote control console to \$1,045 for a radio link repeater over 7 years old.

9. Among all those variables that determined the replacement policy, the dominant variable was obsolescence cost. (Cost attributable to unexploited opportunities due to improvements in equipment.)

10. Observed equipment age related maintenance costs, salvage costs and investment interest rates were contributory variables in determining the replacement policy.

11. No difference in the expected rate of equipment breakdown was observed when comparing policies of 1 or 2 preventive maintenance inspections per year for any equipment type.

12. Systems availability generally decreases as preventive maintenance is done more often. The average measured time to perform breakdown maintenance was 2.5 hrs.; to perform preventive maintenance 1.5 hrs.

13. The "Time Between Failures" probability distribution was shown to be an exponential distribution for all equipment types.

B. RECOMMENDATIONS

The study findings support the following recommendations:

1. A ten to twelve year radio equipment replacement cycle should be instituted. (See Recommendation I, Vol. I, page 13.)

2. Full contract salvage values should be realized on replaced equipment.

3. The established length of the replacement cycle should be used for the depreciation of radio equipment. (An amortization rate of 7% was used in this study. This rate needs to be revised periodically.)

4. All new systems, as well as additions to and modifications of existing communication systems, should be evaluated on the basis of their ownership costs and the expected monetary and non-monetary benefits, based on procedures developed in this study.

5. Presently established systems should be reviewed at time of major system replanning (ten to twelve year planning cycles) for components which appear to be of marginal usefulness. Such components should be subjected to a complete reevaluation.

6. Upgrading of presently established systems with new equipment should not require a complete benefit and cost reevaluation of the systems beyond that noted under 5.

7. The evaluation of available alternatives to meet Forest Service communication requirements should be a continuing process within the Branch of Communications and Electronics.

8. The evaluation of available alternatives for specific applications should be required for all specialized applications or major investments.

9. Preventive maintenance of radio equipment should be phased out following a test period to substantiate the findings of this study. (See Recommendation 11, vol. I, page 27.)

10. Accurate historical radio equipment records should be kept, including:
    a. Purchase cost and date
    b. Salvage values realized
    c. Maintenance records of:
        1) maintenance date
        2) type of maintenance (i.e., PM or BM)
        3) time required for service
        4) parts costs
    d. Periods of time equipment has been removed from service.

C. TELECOMMUNICATIONS REQUIREMENTS EVALUATION PROCEDURES

It is difficult to ascertain benefits attributable to telecommunications with any degree of realism. This makes it necessary to base the proposed procedure on case analyses, whenever possible. The cost-benefit comparison is thus a one-time comparison between the realizable yearly benefits and the prorated, amortized yearly costs of the required systems. No projections of future benefits, except as implied in the assumption of continuing or improving cost-benefit relationships, are proposed for the present.

The criteria used for the evaluation of telecommunication requirements are:

a. Contributions of telecommunications to the safety of Forest Service employees and the public on National Forest lands (including law enforcement).

b. Contributions of telecommunications to fire prevention and suppression activities and to the efficiency of Forest Service resource management.

c. Costs of required systems compared with realized benefits.

The procedure consists of four steps:

Step 1: Describe telecommunication requirements and provide information regarding expected contributions of requested system.

Step 2: Estimate cost of requested communications .

Step 3: Evaluate benefits associated with the requested communications from the input in Step 1 and compare costs to benefits.

Step 4: Review data and decisions concerning approval of request.

In general, Step 1 is the responsibility of the requestor; Steps 2 and 3 are the responsibility of the communications engineers and Step 4 is the responsibility of the appropriate supervisor.

STEP 1: The required input information is that shown on the input data sheet (Exhibit 1, pages 19 - 22). Apart from the general items a, b, c, and d, only those sections should be used which are pertinent to the proposed use of the requested telecommunications. For example, a data transmission requirement may have no fire and safety applications. In this case only non-emergency benefits need be considered. The input sheet can serve small and large requests. For very large requests, the information on the sheet may have to be supplemented by additional items of information for a more detailed evaluation.

The exhibit sheet contains the minimum amount of information necessary for any benefit evaluation. It is therefore necessary to fill in all applicable sections completely. Base your statements on actual incidents whenever possible. Use your knowledge of actual cases to assess the differences in outcome which could be attributed to telecommunications if such were available. Note the experiences of others when applicable. The use of "near miss" or "close call" cases is also appropriate. (These are cases where through some fortuitous set of circumstances actual harm was avoided but the situation would have, with high probability - .9 and .8 respectively -, posed grave danger to those involved under less fortunate circumstances.)

STEP 2: Estimate yearly ownership costs for the requested system. This cost includes the amortized capital costs and maintenance, operating and breakdown costs on a per year basis. If possible, use should be made of Table 1 page 23, or, in the future, of a similar updated instrument. (A table of this type should be revised every 3 years or more often.) Only new or unlisted types of equipment or large investments require the detailed analysis shown in Exhibit 2, pages 24 - 26.

STEP 3: Use information in the requisition input data sheet (Exhibit 1, pages 19 - 22) to compute monetary benefits and to assign weights due to non-monetary considerations. Fire, Safety and Non-Emergency Benefits should be evaluated, separately, as shown in Exhibit 3, pages 27 - 29. The computed benefit cost ratio should, in all cases, be compared with regional telecommunication benefit cost ratios as computed in this study or in an updated version of such. Estimated benefit cost ratios which differ by a wide margin from the regional averages should be re-examined.

The individual cost and benefit evaluation sheets should become an input for updating regional telecommunication cost and benefit averages. This should be a continuing process.

NOTE: Losses to society due to accidents to the public at large must generally be assessed on the basis of published statistics. The present study uses $33,000 (loss of life) and $380 (disabling injury), which is approximately one-half the average cost to Government from fatal and disabling injuries to employees, in agreement with other reported estimates of such costs. Exhibit B9 in the Appendix (page A79) shows the direct costs to the government associated with a fatal accident to have been $65,000 in F.Y. 1970; the average direct cost associated with disabling injuries have been $760 in F.Y. 1970.

These values must be reviewed periodically.

STEP 4: The final evaluation of telecommunication requirements should continue to be based primarily on a critical review of all the information provided in the request and on the basis of the reviewer's general knowledge of the existing situation. The dollar benefit measures constitute only an additional item of information which must be weighed against all other information on record regarding the requirements.

The estimated net benefits or benefit cost ratios should not be used at present to rank individual requirements from different requestors. Such ranking is inadvisable for the time being, because of the wide range of biases of individual requestors. (It is, however, likely that this difficulty will be overcome as the system becomes established.) The estimated benefit cost measures should be used, at present, in the aggregate, for the region as a whole, to provide a measure of the benefits associated with the regions' investments in telecommunications. Used in this way, it can be expected that some distortions due to individual biases will balance each other, especially if a continuous effort is made to use computed regional base line benefit cost ratios for a critical review of the estimated contributions associated with individual requests.

Exhibit 1

COMMUNICATIONS REQUISITION INPUT DATA SHEET*

a. Communications Requirements: ______________________________

____

____

____

b. Non-emergency activities to be benefited:

(1)____________________

(2)____________________

(3)____________________

(4)____________________

c. Period of use and frequency or volume of use for each activity:

____

____

____

____

d. Present situation (Describe briefly problems, if any, due to lack of, or inadequate, communications): ______________________

____

____

____

____

e. <u>FIRE</u> -- if applicable, describe what fire losses you suffered last year (or from ___to___) which would be affected by the requested communication facilities: ______________________________

____

____

(1) Estimated average fire losses in area affected by requested telecommunications:__________ dollars in ________years.

(2) Estimated average fire suppression costs in area affected: __________ dollars in ________ years.

*Not intended for use as a form.

f. What improvements do you expect from the requested communications?

(1) Estimated percent reduction in fire resource losses due to requested telecommunications: _____%

(2) Estimated percent reduction in fire suppression costs due to requested telecommunications: _______%

g. Non-quantifiable benefits to fire functions due to requested communications:______________________________________

____

____

____

h. SAFETY (Employee and Public) -- if applicable, list the number and type of cases which occurred last year (or years) and which would be affected by the requested communications facilities.

(1) Actual loss of life.
(a) Forest Service employees: ____ cases in ____ year(s).
(b) Public : ____ cases in ____ year(s).

(2) Potential "close call" loss of life (probability of loss of life inherent in situation estimated 90% or higher):
(a) Forest Service employees: ____ cases in ____ year(s).
(b) Public : ____ cases in ____ year(s).

(3) Actual disabling injuries:
(a) Forest Service employees: ____ cases in ____ year(s).
(b) Public : ____ cases in ____ year(s).

(4) Potential disabling injuries (probability of disabling injury inherent in situations 80% or higher)
(a) Forest Service employees: ____ cases in ____ year(s).
(b) Public : ____ cases in ____ year(s).

i. Cost to Forest Service of Search and Rescue efforts:
_______dollars/year.

j. What improvements do you expect from the requested telecommunications?

(1) Estimated potential for preventing loss of life in situations where actual or potential loss of life occurred: ____ %

(2) Estimated potential for preventing disabling injury in situations where actual or potential disabling injury occurred: _____%

Exhibit 1 (Continued)

j. (3) Estimated yearly percentage reduction in cost of search and rescue operations: _____ %

k. Other monetary safety benefits from requested telecommunications (describe): ____

____

____

____

(1) Total of "other"benefits: _____ dollars/year

l. Non- quantifiable benefits to safety from requested communications:

____

____

____

____

NON-EMERGENCY BENEFITS

For the functions shown in Item b., estimate espected non-emergency benefits from requested communications:

m.	Direct Time Savings	(1)_____	hours per	_______
		(2)_____	"	_______
		(3)_____	"	_______
		(4)_____	"	_______
n.	And/Or Travel Savings	(1)_____	mileage per	_______
		(2)_____	"	_______
		(3)_____	"	_______
		(4)_____	"	_______

Exhibit 1 (Continued)

o. And/Or Equipment Savings (1)_____ dollars per _______

(2)_____ " _______

(3)_____ " _______

(4)_____ " _______

p. And/Or Productivity Increase (Other than listed above) (1)_____ %

(2)_____ %

(3)_____ %

(4)_____ %

q. And/Or Other (1) ____________________________________

(2) ____________________________________

(3) ____________________________________

(4) ____________________________________

r. Expected Total Yearly Benefits* for each Functional Activity Listed: (1)_____ dollars per year

(2)_____ " "

(3)_____ " "

(4)_____ " "

s. Expected savings in toll or other presently paid communications service charges with requested telecommunications _______ dollars per year.

ADDITIONAL COMMENTS: ____________________________________

____

____

____

____

* Based on a general evaluation of the contributions shown in items m through q.

Table 1. Total ownership costs per year for present types of equipment (New, 1971)

Type of Equipment	Total Ownership Cost per Year (Dollars)
Mobile	244
Portable, light	182
Portable, heavy	294
Base Station, large	596
Base Station, table top	486
Remote Control Console	99
Radio Link,Base Station	653
Radio Link, repeater	1,021
Repeater, AC	771
Repeater, Battery	928

Exhibit 2

COMMUNICATIONS EQUIPMENT COST ANALYSIS *

Equipment Description: ______________________________

____

____

____

Region: __________

Forest: __________

District: __________

Date: __________

Cost Analyst: __________

A. Capital Costs

1.	Item Purchase Price	$______		
2.	Est. Years of Life or Use	______		
3.	Est. Salvage Value	$______		
4.	Costs to be Depreciated (1-3)		$______	
5.	Installation Cost (W.O. Bldg.)		$______	
6.	Adm. Cost to Obtain Inventory, etc. equipment		$______	
7.	Total Capital Cost (4+5+6)		$______	
8.	Capital Recovery Factor for Comm. Equipment (appendix table A1)	______		
9.	Amortized Equipment Capital Cost/Yr. (7 x 8)		$______	
10.	If Equipment Housing needed Installed Cost	$______		
11.	Est. Years of Life or Use	______		
12.	Capital Recovery Factor for Building or Housing (appendix table A1)	______		
13.	Amortized Housing Capital Cost/Yr. (10 x 12)		$______	
14.	Total Capital Cost/Yr. (9+13)			$______

* Not intended for use as a form.

Exhibit 2 (continued)

B. Operations Costs

Estimate Annual Cost for:

15. Power (batteries) $________

16. Shop Space $________

17. Inventory $________

18. Administration Cost $________

19. Other $________

20. Total Annual Operations Costs (15+16+17+18+19) $________

C. Maintenance & Repair Costs

21. Est. Maintenance Cost/Yr.

    a. Labor $________

    b. Parts $________

    c. Travel or Transport $________

    d. Per diem $________

    e. Overhead $________

22. Total Annual Maint. Cost (a+b+c+d+e) $________

Exhibit 2 (continued)

23. Est. Repair Cost/Yr. if separate from 1.

    a. Labor $_______

    b. Parts $_______

    c. Travel or Transport $_______

    d. Per diem $_______

    e. Overhead $_______

24. Total Annual Repair Cost (a+b+c+d+e) $_______

25. Total Annual Maintenance & Repair Cost (22+24) $_______

D. Breakdown Cost

26. Est. Breakdown Cost/Yr. $_______

E. Total Annual Equipment Cost (14+20+25+26) $_______

Exhibit 3

BENEFIT-COST COMPUTATION SHEET*

FIRE BENEFITS

1. Benefits from reduced resource losses:

Exhibit 1, item e(1) x f(1) ÷ 100 = _____ dollars in ____ year

a. Prorated yearly resource benefits = __________$/yr.

2. Benefits from reduced fire suppression costs:

Exhibit 1, item e(2) x f(2) ÷ 100 = _____ dollars in ____ year

a. Prorated yearly suppression benefits = _________$/yr.

3. Total estimated fire benefits: _____________$/yr.
(above items 1a + 2a)

SAFETY BENEFITS

4. Benefits from reduced risk of loss of life in life endangering or potentially life endangering situations:

Forest Service employees (Exhibit 1, items h(1a), h(2a), j(1)):

$64,000** x h(1a) x j(1) ÷ 100 = ________ dollars in ____ years

$57,6000 x h(2a) x j(1) ÷ 100 = ________ dollars in ____ years

a. Yearly prorated subtotal = _____________$/yr.

Public (Exhibit 1, items h(1b), h(2b), j(1)):

$33,000 x h(1b) x j(1) ÷ 100 = ________ dollars in ____ years

$29,700 x h(2b) x j(1) ÷ 100 = ________ dollars in ____ years

b. Yearly prorated subtotal = ____________$/yr.

*Not intended for use as a form.
**Includes $1000 residual costs for injury, shock, etc., in case of successful rescue.

Exhibit 3 (continued)

5. Benefits from reduced risk of disabling injury:

Forest Service employees (Exhibit 1, items h(3a), h(4a), j(2):

$760 x h(3a) x j(2) ÷ 100 = ________ dollars in ____ years

$608 x h(4a) x j(2) ÷ 100 = ________ dollars in ____ years

a. Yearly prorated subtotal = ________ $/yr

Public (Exhibit 1, items h(3b), h(4b), j(2):

$380 x h(3b) x j(2) ÷ 100 = ________ dollars in ____ years

$304 x h(4b) x j(2) ÷ 100 = ________ dollars in ____ years

b. Yearly prorated subtotal = ________ $/yr

6. Benefits from reduced search and rescue costs:

Exhibit 1, item i x j(3) ÷ 100 = ________ $/yr

7. Other monetary safety benefits shown in Exhibit 1; item k(1): ________ $/yr

8. Total Safety Benefits (above items 4a+ 4b+ 5a+ 5b+ 6 +7) ________ $/yr

NON-EMERGENCY BENEFITS

(computations from input data sheet items c and r)

9. Function (item c(1)) ________________ Benefits (item r(1)) ________________ $/yr

10. Function (item c(2)) ________________ Benefits (item r(2)) ________________ $/yr

11. Function (item c(3)) ________________ Benefits (item r(3)) ________________ $/yr

12. Function (item c(4)) ________________ Benefits (item r(4)) ________________ $/yr

13. Toll charge savings and other non-emergency benefits shown in Exhibit 1:

a. Toll charge savings (item s) __________ $/yr

b. Other non-emergency benefits __________ $/yr

14. Total Non-Emergency Benefits ______ $/yr
(above items 9+10+11+12+ 13a+13b)

15. TOTAL ESTIMATED BENEFITS ______ $/yr
(above items 3,8,14)

16. Total estimated cost of ownership ______ $/yr
(from cost estimate)

17. ESTIMATE OF NET BENEFITS ______ $/yr
(above items 15-16)

18. Benefit cost ratio: ______
(item 15 ÷ 16)

19. Weight due to non-quantifiable benefits: ______
(1 standard, 2 important additional considerations, 3 urgent)

20. Recommendations ____

____

____

____

____

PART II

FIELD RADIO SYSTEM COSTS AND BENEFITS

A. COST ANALYSIS

The communications costs examined in this section of the report are capital costs, operating costs and rental costs of field radio equipment.

1. CAPITAL COSTS

Table 2 (page 39), shows the 1971 contract bid price for mobile, portable, various base stations, radio links and repeater units bought by the Forest Service. The costs per unit range from $275 for a remote control console to over $3000 for a radio link repeater.

The average capital cost by type of radio for nine different kinds of radio installations is compiled in Table 3 (page 40). The total capital cost is calculated to equal the purchase cost of the particular radio item (1971 data) minus the salvage value of the radio at the end of its suggested ten-year life span plus the average installation cost of the unit plus the administrative cost to acquire the installation. The purchase cost is taken from the previously mentioned Table 2 (page 39). The estimated salvage value was provided by the Regional Electronics Engineers in their questionnaires. The salvage value, though negligible, is included for the completeness of the logic. The installation cost includes labor, hardware, antenna, and antenna masts where necessary, power lines, voltage regulators, duplexers, lightning protection, etc. This figure was derived from item 22 in the Regional Engineer's questionnaire. Finally, $50 was added as an estimate for the administrative costs to manage the purchase and installation of this type of radio equipment. Remote base stations, repeaters and radio links in some instances must be housed in a separate shed because no protective housing is available. Where such is necessary, an average cost of $2000 must be added to the total capital cost. Since the cost of an enclosure varies considerably between regions, it may be advisable for each region to provide its own cost figure rather than using the average cost of $2000.

For cost benefit calculations it is necessary to derive a capital cost per year figure which can be compared with the expected benefits on a yearly basis. The equipment obsolescence section of this study suggests that the obsolescence period varies by type of equipment and by the development rate for new technology. A reasonably conservative ten-year depreciation period is recommended for general cost studies even though in specific instances replacement after a 7 or 8-year period may be economically feasible. While Forest Service personnel have traditionally used the straight line amortization calculation (i.e. capital cost divided by the number of years of expected life), this is not recommended in the light of recent directives by the Office of Management and Budget. It is also fundamentally unrealistic to disregard the cost of money to the Government since investments are paid for through loans at varying interest rates. The Office of Management and Budget recommends that varying interest rates up to 12% be experimented with for sensitivity analysis. This study recommends that at this time

(1971) an interest rate of 7% be used; this represents a reasonable approximation of the current long and short term average borrowing rates for the Government.

The recommended procedure for amortizing the capital cost on an annual basis is by use of the Capital Recovery Factor (C.R.F.). The C.R.F. provides for sinking fund depreciation plus the interest cost on the initial investment. The sinking fund depreciation is a method for accumulating sufficient capital on an annual basis so that at the end of the amortization period (expected life span of the equipment) the yearly deposits plus the interest earned on them will be sufficient to replace the worn-out equipment with an equivalent new piece of equipment. All depreciation procedures recover only the cost of the initial investment; they do not take into account price rises due to inflation or improved technology. If at the time of replacement costs have increased, the additional costs must be provided from new capital (an increase in the budget or an addition to the Working Capital Fund). To place a surcharge for potential inflation or other increases in cost on present equipment would be unfair to present year cost accounting and to cost benefit evaluations for the present piece of equipment.

The Capital Recovery Factors (C.R.F.) can be found in any engineering economy reference and are given in Appendix Table A1 at 6%, 7%, 8%, 10% and 12%, for expected life spans of 7, 10, and 12 years. To obtain the amortized capital cost per year for any piece of equipment, multiply the total initial cost of that piece of equipment (as given in Table 3, page 40) times the C.R.F. appropriate for the life of the equipment at the current rate of interest.

Table 4, page 41 gives the amortized capital cost (for a 10-year life span at 7% interest rate)of the nine types of radio equipment listed in Table 3, page 40. Column 1 of Table 4, shows the amortized capital cost if no additional building or housing is required to protect the piece of equipment; column [illegible] shows the amortized capital cost per year for remote base stations, repeaters and radio links if an additional new shed must be constructed at the average Forest Service purchase and installation cost of $2000. The building is amortized over a 15 year period which, at 7%, comes out to $220 per year, Those regions constructing a building of brick or other long wearing materials should use an appropriate depreciation time for such an installation.

For reference, Appendix Table A2 lists the amortized capital cost per year at 7% interest for a depreciation period of 7, 10, 12 and 15 years for capital costs ranging from $100 to $4000 in $100 increments. This table will allow rapid rough estimates for an initial cost benefit analysis if the engineer can estimate to the closest $100 the expected total capital cost of the item to be purchased. To this he then can add average operating, maintenance and repair costs as delineated in Appendix Tables A3 and A4. If benefits fall short of meeting these expected cost figures, the facilities request might then be rejected without further detailed analysis. If the cost benefit analysis seems favorable, specific capital cost figures should then be compiled and substituted and the precise calculation using the respective C.R.F. should be made.

2. OPERATING COSTS

a. Power and Miscellaneous costs

Included are power, batteries, shop or office space required for managing and maintaining the communications system, administrative costs including salary and administrative travel, etc. It does not include maintenance cost nor the wages of the operator of the communications unit. These costs were compiled from the regional questionnaire, item 21 (Appendix page A29) and are presented and summarized in Table 5, page 42. Since the differences in such costs between similar pieces of equipment are hard to define, operations costs have been tabulated only for the major categories; fixed base stations, mobiles, light and heavy portables. The averages range from $24/yr for mobiles to $104/yr for fixed base stations. Since the absolute dollar differences between the regional averages and the individual regional costs are not very large, except possibly for fixed base stations in Regions 5 and 6 and heavy portables in Region 4, the regional averages appear to be sufficiently precise for use in cost benefit evaluations.

b. Maintenance and repair costs

No separate cost figures are available to differentiate between preventive maintenance and corrective maintenance (repair). Therefore, no correlations could be calculated between frequency and cost of preventive versus corrective maintenance. In another section of this study these maintenance relationships have been explored using independently collected data.

Maintenance and repair costs have been broken down into labor costs, (direct maintenance labor plus travel and per diem costs), and parts costs. The cost of the maintenance facilities and maintenance spare parts inventory, etc., was prorated as part of the miscellaneous cost. All maintenance costs in this section are based on the experiences from the existing equipment mix (from vacuumm tubes to solid state). As our inventory shifts further to solid state, new maintenance costs must be substituted. Maintenance costs were collected separately for relatively new equipment (less than 7 years of age) and for older equipment (above 7 years of age) because of the tendency of these costs to increase with increased age of equipment. This breakdown is supported by the findings in the preventive maintenance policy section of this study. Only these two age classes were established because the base data available to the engineers for compiling maintenance costs were not sufficient to allow a year-by-year breakdown. The 7 year delineation point was selected in consultation with the electronic engineers as the most likely breakpoint between old and new equipment.

Regional average costs for maintenance and repair of old and new equipment, separated by type of equipment, is shown in Appendix Tables A3 and A4. The maintenance cost is broken down into labor and parts cost. The average total maintenance cost ranges from a low of $86 per year for a new light portable radio to a high of $290 a year for old radio links. The cost variations between regions for any specific piece of equipment range as high as eight to one. Each region should therefore

decide whether they want to use the average regional cost for their own cost benefit calculations or whether they should substitute actual regional costs.

c. Unit breakdown cost per year

The breakdown cost for a piece of equipment is extremely hard to determine. It consists of the costs associated with the repair of the equipment (generally covered in maintenance costs); the direct labor cost associated with compensating for the breakdown (e.g., walking or driving to the nearest other communications link); and the cost of spare equipment required to substitute for the original equipment while it is out of service; and finally the opportunity cost lost because the initial piece was not serviceable when needed. Such opportunity costs can run very high and could include the cost of life or health during an emergency, the cost of fire that went out of control while no communications were available at the critical moment, etc. The lost opportunity cost tends to be by far the highest of these costs. Because of the complex probabilistic nature of determining these costs they were not included in this evaluation. Repair cost, the second highest magnitude item in the series, has already been covered under maintenance and repair cost.

The cost of an alternate communications link was calculated to be the salary cost during the time period required to obtain alternate communications plus the direct cost of the alternate communications link (usually a long distance telephone call). This sum needs to be multiplied by the probability of its occurrence since in most instances of radio failure no special effort would be made to obtain immediate alternate communications. This cost variable was insignificantly small and has been included only for completeness of the analysis.

The cost of having substitute or spare equipment available during periods of equipment breakdown was calculated as the average capital cost per year for the corresponding piece of equipment from Table 4, page 41 (not including building costs since presumably the building would remain available) multiplied by the breakdown occurrence in number of days per year. The average experienced downtime per year for three types of equipment was obtained from the district rangers' and technicians' questionnaires (Table 6, page 43). The existing downtime was used for cost calculations rather than the acceptable downtime because the attainability of that level is uncertain. The average breakdown cost per year ranges from a low of $2.26 for remote console to a high of $18.38 for a radio link repeater (Table 7, page 44). These are modest costs as compared to the maintenance and capital costs.

3. TOTAL EQUIPMENT COST

The total ownership cost per year for a piece of radio equipment is the sum of the previously discussed costs. This is presented in Table 8, page 45 for the eight types of radio equipment covered by this analysis. Separate costs are shown for relatively new equipment (less than 7 years old) and for relatively old equipment (above 7 years old) because of the sometimes appreciable differences in maintenance costs per year. The

capital costs naturally remain constant over the life of the equipment. Operating and breakdown costs have been assumed not to vary with age. However, even a considerable variation (50%) of the breakdown cost would not be significant.

If equipment is kept beyond its estimated life period (ten years for these calculations), then the capital cost will drop out because the equipment has been completely depreciated and the total ownership costs from then on will be the remaining maintenance costs, operating costs, and breakdown costs. Indefinite retention of the equipment might naturally drastically increase the maintenance and breakdown costs, so that separate calculations might need to be made. Because of the concurrent high cost of general obsolescence, more fully explored in a later section of this report, a separate cost analysis for obsolete equipment was not made in this part of the study.

The total cost figures from Table 8, page 45-49 should and can reliably be used as cost references for cost benefit analyses of additional equipment requirements for the field or for network expansions or redesign where multiples of these units are being cost-benefit evaluated. Large network expansions (i.e. the addition of a substantial number of units to an existing network) can, in many instances, incur additional costs in the form of modified network operating characteristics such as congestion and consequent delays. If the existing network has approached maximal allowable congestion and there is a good chance that the additional units will impose a sufficient load burden to severely decrease the operating effectiveness of the network, the engineer should make an appropriate decision about the permissibility of adding additional units independent of the direct cost-benefit ratio calculations. Another alternative is to pull low priority radios off the existing network and substitute the requested new facilities if the new facilities have a higher cost-benefit ratio compared to existing units with marginal utilization.

In most cases, and especially for complex installations, the engineer must calculate the precise capital and maintenance costs, especially when these are expected to vary widely from the presented averages. This step can, in many cases, be eliminated if the preliminary cost-benefit analysis, using the average cost data, clearly indicates that the requested or recommended installations are economically not feasible.

As labor and material costs continue to change over the ensuing years and the purchase price of equipment consequently changes, it will be necessary to periodically update these tables. This should be the responsibility of the Communications and Electronics Branch in the Washington Office which also must decide when sufficient variation has occurred to warrant the updating. If the same procedure is used as outlined in the report, such an updating process can probably be accomplished with two man-weeks of effort.

The most uncertain figure in these tabulations is the maintenance cost. If we look at out-of-pocket expenses, we can theoretically assume that the labor component of maintenance costs will not change drastically as long as the existing maintenance technicians are sufficient to do the work. If preventive maintenance is eliminated, as recommended in

this study, or increased in the future under as yet unknown conditions, the maintenance labor component will be significantly affected. This difference can be a quantum jump if a technician is released or an additional technician must be hired by a forest. Maintenance cost analysis should always be based on the actual cost of labor expended on a unit or group of units rather than burdening existing communication units with the total salary of an additional technician hired because of overload, if the new man only spends part of his time on maintenance. Neither does maintenance cost shrink to zero if a forest releases their technician and shares the repair work with another forest.

When annual ownership cost (Table 8, page 45-49) is plotted against initial item purchase cost (Table 2, page 39) we see that ownership cost increases with purchase cost, but at a diminishing rate (Fig. 1, page 50). This is supported by intuitive judgment.

If it is assumed that this purchase to ownership cost relationship remains relatively stable over time, then the curve in Fig. 1 can be used for a rapid approximation of annual ownership cost if the purchase cost is known. This ownership cost approximation may be sufficient in most cases for a preliminary benefit-cost evaluation of new communications requirements. The curve has been plotted from present (1971) cost relationships.

4. COST VARIABILITY

It is known that radio equipment purchase and installation costs are relatively non-elastic with the quantity purchased by any unit (forest or region); at the forest level because of Service-wide contract pricing and at the regional level because particular installations are generally distance separated so that simultaneous multiple installations are not feasible. On the other hand maintenance and repair costs are generally hypothesized to be functionally related to both the number of units serviced as well as their ages. A number of hypotheses were therefore formulated and tested. They were:

1. Total time spent per unit on maintenance and repair will decrease with the number of units of each type of equipment available on a district.

2. Total time spent on maintenance and repair will increase with the average age of units available on the district or forest.

3. Average maintenance frequency will increase with the average age of units at the district or forest.

4. Failure rate for each type of equipment will increase with average age of equipment.

5. Downtime for each type of equipment will increase with average age of equipment.

Failure rate analysis could not be made because the data on failure rates in the questionnaire were inconsistent due to apparent misinterpretation of the question. The other expected hypotheses were not

supported by the data. The data instead showed random relationships apparently due to confounding factors such as skill of technician, pressure to perform tasks, and methods and procedures used by the technician in servicing of equipment. Hence, no dynamic recommendations can be made suggesting optimum staffing of technicians as a function of the number of radio units, their age, condition or utilization to reduce the maintenance costs (see also discussion under maintenance standards).

5. RENTAL VS. PURCHASE COST COMPARISON

Rental costs for various radio items and the contract reference is given in Appendix Table A5, page A7. These contracts were for 1967 - 1968 and the rate is based on renting all radio items for a forest. To update the data for comparison with our 1970-1971 Forest Service cost data, a conservative inflationary increase of 8% is assumed for the years 1968-1970. The rental rates are based on observing the minimum rental period (3 years). A penalty clause increases the monthly rental rate substantially for shorter rental periods.

The rental rates without maintenance are compared to annual capital costs of Forest Service owned radios minus cost of antenna, mast, antenna installation and the $50 administrative cost since paper work for rental is at least as costly as for purchase. This modified capital cost is then amortized over a 10 year life at 7% as in Table 4, page 41. The contract rental rates were averaged for each type of equipment for this comparison, as only average capital cost figures are available. One tenth of the contract installation and removal cost is added to the annual rental rate. This comparative data is presented in Table 9, page 51.

Repeaters, portables, and mobiles are far cheaper to own than to rent. The rental and ownership cost for base stations are the same within the sensitivity of the data. The difference between rental and Forest Service owned equipment cost ranges from -4% to 226% higher for rental. In number of units, mobiles portables, and repeaters far outweigh fixed base stations at any forest so that the rental cost for all the radio units at a forest or region would be approximately three times as expensive as Forest Service ownership. The rental fee is based on a minimum rental period. A shorter rental period incurs a service termination fee or sharply increased rates, greatly favoring Forest Service ownership.

A comparison of rental rates inclusive maintenance with Forest Service ownership including maintenance is difficult because the contractor will repair and maintain only at his central shop. This requires that the Forest Service transports and delivers all items to his shop. Because the unit would be out of service for a much longer period, the unavailability cost to the Forest Service would sharply increase. For comparison purposes, the unavailability cost under rental conditions is estimated to be four times that under Forest Service field repair conditions. Transport and pickup costs to and from the central contractor repair center are estimated to be $25.00 per unit. The cost comparison with maintenance is shown in Table 10, page 52. This comparison also shows a consistent economic advantage for Forest Service owned and

maintained equipment over rented equipment with the exception of fixed base stations which, as discussed above, are relatively few in number. This comparison is heavily biased in favor of the contractor since the travel cost is likely to be often far higher than estimated and the unavailability cost due to central repair and lack of field emergency repair is greater than charged. Furthermore, Forest Service technicians would still be required for fire and other specialized duties. Their marginal cost for these assignments would greatly increase if their base cost were not carried by routine equipment service functions.

Table 2. Average purchase cost for radio sets in 1971.*

Radio Item	Average Purchase Cost
Mobile	$ 400.00
Portable	
Light	506.00
Heavy	824.00
Base Station	948.00
Base Station - Table top	677.00
Remote Control Console	275.00
Radio Link	
Base	1,329.00
Repeater	3,023.00
Repeater	
AC	1,290.00
Battery	2,099.00

* not including installation

Ref: Bid - FS-5-71

Table 3. Capital cost by type of radio

1. Mobiles	=	$ 500.00				
C_c	=	400.00	- $21	+ $71	+ $50	
2. Portable Light	=	$ 498.00				
C_c	=	506.00	- 8	+ 0	+ 50	
3. Portable Heavy	=	$ 814.00				
C_c	=	824.00	- 10	+ 0	+ 50	
4. Base Station, Large	=	$1,639.00				
C_c	=	948.00	- 23	+ 664	+ 50	1/
5. Base Station Table Top	=	$1,154.00				
C_c	=	677.00	- 23	+ 450	+ 50	
6. Remote Control Console	=	$ 339.00				
C_c	=	275.00	- 21	+ 35	+ 50	
7. Radio Link						
a. Base Station	=	$2,020.00				
C_c	=	1,329.00	- 23	+ 664	+ 50	
b. Base Repeater	=	$4,398.00				
C_c	=	3,023.00	- 45	+ 1370	+ 50	1/
8. Repeater A. C.	=	$2,639.00				
C_c	=	1,290.00	- 23	+ 1322	+ 50	1/
9. Repeater Battery	=	$3,642.00				
C_c	=	2,099.00	- 23	+ 1516	+ 50	1/

$$C_c = C_p - S + C_i + C_a$$

Where:
- C_c = Total Capital Cost
- C_p = Purchase Cost of Radio Item (1971)
- S = Salvage Value of Radio Item
- C_i = Installation Cost Without Building 1/ but includes antenna mast
- C_a = Administration Cost

1/ For building to house equipment, where necessary, add average cost of $2000.00

Table 4. Amortized capital cost per year

Type of Equipment	Amortized* Cost/yr Without Bldg.	With Bldg. (add $220/yr)
Mobile	$ 71.00	--
Portable (light)	71.00	--
Portable (Heavy)	116.00	--
Base Station, Large	233.00	$453.00
Base Station, Table Top	164.00	--
Remote Control Console	48.00	--
Radio Link		
Base Station	288.00	508.00
Repeater	626.00	846.00
Repeater, (A.C.)	376.00	596.00
Repeater, Battery	519.00	739.00

Amortized Capital Cost = Capital Cost (Table 3) x Capital Recovery Factor (CRF)

Radio shed has a life estimate of 15 yrs, and an average capital cost of $2000.

Amortized cost for radio shed = $2000 x 0.1098 (CRF, 15 yrs, 7%.)= $220

*10 yr. Life @ 7%; CRF=0.1424

Table 5. Power and miscellaneous* operating costs per year.

Region	Fixed Base	Mobiles	(H) Portable	(L) Portable
1	$ 77	$17	$28	$24
2	NA	NA	NA	NA
3	110	-	20	19
4	104	52	80	48
5	200	35	50	35
6	190	28	43	43
8	60	10	25	10
9	90	4	20	13
Weighted average, all regions	$115	$24	$47	$32

* Inventory, shop space, administration costs, but without maintenance costs and wages of operator.

Table 6. Equipment downtime in days.

	Type of Equipment					
	Base Stations		Mobiles		Portables	
	Season:		Season:		Season:	
	All	Summer	All	Summer	All	Summer
Average of downtime estimates by:						
District Ranger	3-3/4		2-3/4		3	
Technician	2-1/4		2-1/2		2-3/4	
Average of acceptable downtime suggested by:						
District Ranger	1-1/2	1	1-1/2	1	1-1/2	1
Regional Electronics Engr.	1-1/2	3/4	3-3/4	3	5-1/2	3-1/2

Table 7. Average unit breakdown cost/year.

Type of Unit	Av. No. of Breakdowns Per Year 1/	Av. Capital Cost/Year (Table)	Av. Length of Breakdown (days) ÷ 365 2/	Av. Alternate Communication Cost 3/	Av. Breakdown Cost/Year 4/
Mobile	2.75	$71.00	2.50	$1.25	$4.79
Portable (light)	3.00	71.00	2.75	1.25	5.34
Portable (heavy)	3.00	116.00	2.75	1.25	6.36
Base Sta. (Large)	3.75	233.00	2.25	1.04	9.30
Base Sta. (Tabletop)	3.75	164.00	2.25	1.04	7.69
Remote Control Console	2.75	48.00	2.25	.52	2.26
Radio Link: Base Sta.	3.75	288.00	2.25	1.04	10.58
Radio Link: Repeater	3.75	626.00	2.25	1.04	18.38
Repeater (A.C.)	3.75	376.00	2.25	1.04	12.60
Repeater (Battery)	3.75	519.00	2.25	1.04	15.90

1/ District Ranger Questionnaire item 27. 2/ Technicians Questionnaire item 28.

3/ Calculated as follows:
Mobiles and Portables

$$\left[\left(\text{1hr. travel time(rnd trip)} \times \underset{(GS\text{-}5/4)}{\$3.67 \text{ salary}}\right) + \$.50 \text{ (telephone)}\right] \times .3 \text{ (probability of occurrence)} = \$1.25$$

Fixed Stations

$$\left[\left(\text{2hr. travel time(rnd trip)} \times \underset{(GS\text{-}4/4)}{\$3.28 \text{ salary}}\right) + \$.50 \text{ (telephone)}\right] \times .15 \text{ (probability of occurrence)} = \$1.04$$

4/ $$\text{Av. Breakdown Cost/year} = \text{Av. No. of Breakdowns/year} \times \left[\left(\text{Av. Capital Cost/Year} \times \text{Av. Length of Breakdown (Days)}\right) + \text{Av. Alternate Comm. Cost}\right]$$

Table 8. Average total ownership cost/year

Type of Equipment	Age Code*	Capital cost/yr	Maintenance cost/yr**	Operating cost/yr**	Breakdown cost/yr	Total Ownership cost/yr
Mobile	0	$ 71.00	$144.00	$ 24.00	$ 5.00	$ 244.00
	1	71.00	166.00	24.00	5.00	266.00
Portable (light)	0	71.00	74.00	32.00	5.00	182.00
	1	71.00	77.00	32.00	5.00	185.00
Portable (heavy)	0	116.00	125.00	47.00	6.00	294.00
	1	116.00	151.00	47.00	6.00	320.00
Base Stn. (large)	0	233.00	239.00	115.00	9.00	596.00
	1	233.00	263.00	115.00	9.00	620.00
Base Stn. Table Top	0	164.00	199.00	115.00	8.00	486.00
	1	164.00	217.00	115.00	8.00	504.00
Remote Control Console	0,1	48.00	25.00	24.00	2.00	99.00
Radio Link, Base stn.	0	288.00	239.00	115.00	11.00	653.00
	1	288.00	263.00	115.00	11.00	677.00
Radio Link, Repeater	0	626.00	262.00	115.00	18.00	1021.00
	1	626.00	286.00	115.00	18.00	1045.00
Repeater, AC	0	376.00	267.00	115.00	13.00	771.00
	1	376.00	281.00	115.00	13.00	785.00
Repeater, Battery	0	519.00	249.00	144.00	16.00	928.00
	1	519.00	283.00	144.00	16.00	962.00

* Age Code: 0 = new to 7 yrs. and 1 = above 7 yrs.

** Based on weighted averages for all regions for which data available (i.e.,regions: 4,5,6,9).

Table 8 Cont. Average total ownership cost/year for region 4.

Type of Equipment	Age* Code	Capital cost/yr	Maintenance cost/yr	Operating cost/yr	Breakdown cost/yr	Total Ownership cost/yr
Mobile	0	$ 71.00	$200.00	$ 52.00	$ 5.00	$ 328.00
	1	71.00	261.00	52.00	5.00	389.00
Portable	0	71.00	124.00	48.00	5.00	248.00
(light)	1	71.00	153.00	48.00	5.00	277.00
Portable	0	116.00	162.00	80.00	6.00	364.00
(heavy)	1	116.00	192.00	80.00	6.00	394.00
Base Stn.	0	233.00	224.00	104.00	9.00	570.00
(large)	1	233.00	304.00	104.00	9.00	650.00
Base Stn.	0	164.00	199.00	104.00	8.00	475.00
Table Top	1	164.00	217.00	104.00	8.00	493.00
Remote Control Console	0,1	48.00	25.00	24.00	2.00	99.00
Radio Link,	0	288.00	224.00	104.00	11.00	627.00
Base Stn.	1	288.00	304.00	104.00	11.00	707.00
Radio Link,	0	626.00	224.00	104.00	18.00	972.00
Repeater	1	626.00	262.00	104.00	18.00	1010.00
Repeater, AC	0	376.00	224.00	104.00	13.00	717.00
	1	376.00	286.00	104.00	13.00	779.00
Repeater,	0	519.00	236.00	144.00	16.00	915.00
Battery	1	519.00	259.00	144.00	16.00	938.00

* Age Code: 0 = new to 7 yrs. and 1 = above 7 yrs.

Table 8 Cont. Average total ownership cost/year for region 5.

Type of Equipment	Age Code*	Capital cost/yr	Maintenance cost/yr	Operating cost/yr	Breakdown cost/yr	Total Ownership cost/yr
Mobile	0	$ 71.00	$198.00	$ 35.00	$ 5.00	$ 309.00
	1	71.00	198.00	35.00	5.00	309.00
Portable	0	71.00	112.00	35.00	5.00	223.00
(light)	1	71.00	112.00	35.00	5.00	223.00
Portable	0	116.00	192.00	50.00	6.00	364.00
(heavy)	1	116.00	192.00	50.00	6.00	364.00
Base Stn.	0	233.00	244.00	200.00	9.00	686.00
(large)	1	233.00	274.00	200.00	9.00	716.00
Base Stn.	0	164.00	199.00	200.00	8.00	571.00
Table Top	1	164.00	217.00	200.00	8.00	589.00
Remote Control Console	0,1	48.00	25.00	24.00	2.00	99.00
Radio Link,	0	288.00	244.00	200.00	11.00	743.00
Base Stn.	1	288.00	274.00	200.00	11.00	773.00
Radio Link,	0	626.00	249.00	200.00	18.00	1093.00
Repeater	1	626.00	274.00	200.00	18.00	1118.00
Repeater, AC	0	376.00	274.00	200.00	13.00	863.00
	1	376.00	274.00	200.00	13.00	863.00
Repeater,	0	519.00	249.00	160.00	16.00	944.00
Battery	1	519.00	274.00	160.00	16.00	969.00

* Age Code: 0 = new to 7 yrs. and 1 = above 7 yrs.

Table 8 Cont. Average total ownership cost/year for region 6.

Type of Equipment	Age Code*	Capital cost/yr	Maintenance cost/yr	Operating cost/yr	Breakdown cost/yr	Total Ownership cost/yr
Mobile	0	$ 71.00	$ 75.00	$ 28.00	$ 5.00	$ 179.00
	1	71.00	78.00	28.00	5.00	182.00
Portable (light)	0	71.00	36.00	43.00	5.00	155.00
	1	71.00	46.00	43.00	5.00	165.00
Portable (heavy)	0	116.00	23.00	43.00	6.00	188.00
	1	116.00	46.00	43.00	6.00	211.00
Base Stn. (large)	0	233.00	297.00	190.00	9.00	729.00
	1	233.00	312.00	190.00	9.00	744.00
Base Stn. Table Top	0	164.00	199.00	190.00	8.00	561.00
	1	164.00	217.00	190.00	8.00	579.00
Remote Control Console	0,1	48.00	25.00	24.00	2.00	99.00
Radio Link, Base Stn.	0	288.00	297.00	190.00	11.00	786.00
	1	288.00	312.00	190.00	11.00	801.00
Radio Link, Repeater	0	626.00	297.00	190.00	18.00	1131.00
	1	626.00	312.00	190.00	18.00	1146.00
Repeater, AC	0	376.00	297.00	190.00	13.00	876.00
	1	376.00	312.00	190.00	13.00	891.00
Repeater, Battery	0	519.00	297.00	160.00	16.00	992.00
	1	519.00	312.00	160.00	16.00	1007.00

* Age Code: 0 = new to 7 yrs. and 1 = above 7 yrs.

Table 8 Cont. Average total ownership cost/year for Region 9.

Type of Equipment	Age Code*	Capital cost/yr	Maintenance cost/yr	Operating cost/yr	Breakdown cost/yr	Total Ownership cost/yr
Mobile	0	$ 71.00	$100.00	$ 4.00	$ 5.00	$ 180.00
	1	71.00	115.00	4.00	5.00	195.00
Portable	0	71.00	60.00	13.00	5.00	149.00
(light)	1	71.00	70.00	13.00	5.00	159.00
Portable	0	116.00	60.00	20.00	6.00	202.00
(heavy)	1	116.00	70.00	20.00	6.00	212.00
Base Stn.	0	233.00	120.00	90.00	9.00	452.00
(large)	1	233.00	135.00	90.00	9.00	467.00
Base Stn.	0	164.00	199.00	90.00	8.00	461.00
Table Top	1	164.00	217.00	90.00	8.00	479.00
Remote Control Console	0,1	48.00	25.00	24.00	2.00	99.00
Radio Link,	0	288.00	120.00	90.00	11.00	509.00
Base Stn.	1	288.00	135.00	90.00	11.00	524.00
Radio Link,	0	626.00	240.00	90.00	18.00	974.00
Repeater	1	626.00	310.00	90.00	18.00	1044.00
Repeater, AC	0	376.00	225.00	90.00	13.00	704.00
	1	376.00	275.00	90.00	13.00	754.00
Repeater,	0	519.00	180.00	112.00	16.00	827.00
Battery	1	519.00	200.00	112.00	16.00	847.00

* Age Code: 0 = new to 7 yrs. and 1 = above 7 yrs.

Figure 1. Annual ownership cost versus initial purchase cost ($) for radio units.

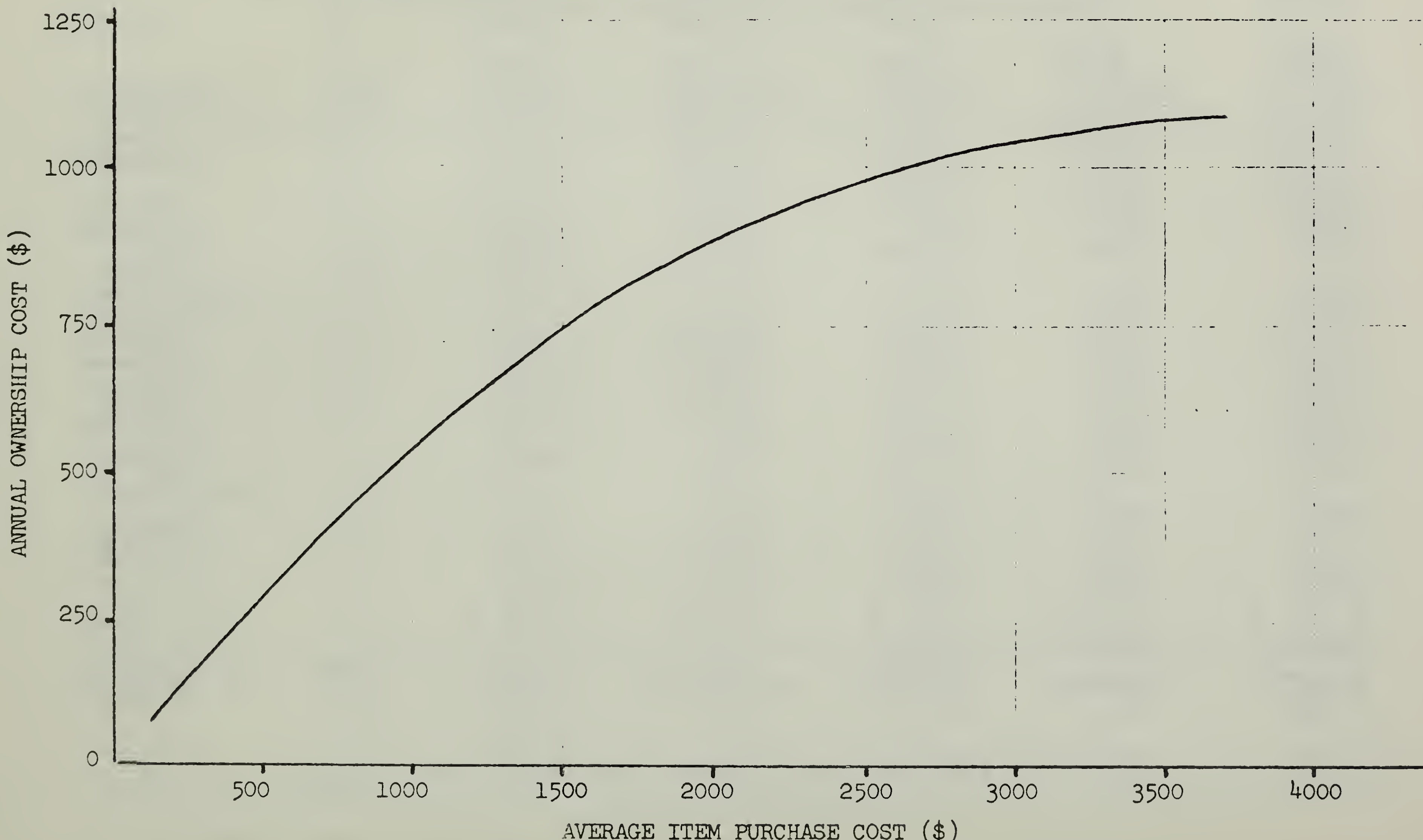


Table 9. Cost comparison - radio rental W/O maintenance versus F.S. ownership.

Type of Equipment	Rental w/o Maintenance per year	F. S. Capital cost/yr	% Difference over F. S. cost
Mobile	$230.69	$ 71.00	226
Portable, Light	194.07	71.00	164
Portable, Heavy	265.60	116.00	207
Base Station, Large	228.38	233.00	-2
Base Station, Table Top	156.77	164.00	-4
Repeater, A.C.	583.83	376.00	55
Av. % Difference			108

Table 10. Cost comparison - Radio rental with maintenance versus Forest Service ownership.

Type of Equipment	Rental costs with maintenance per year	F. S. Costs (Capital unavailability and maintenance) per year	% Difference over F. S. Cost
Mobile	$ 349.17	$ 207.00	69
Portable			
Light	305.03	162.00	88
Heavy	372.92	231.00	62
Base Station			
Large	439.94	478.00	-8
Table Top	310.83	372.00	-16
Repeater, A.C.	818.83	640.00	28
Average % Difference			37

B. BENEFITS ATTRIBUTABLE TO PRESENT FIELD TELECOMMUNICATION SYSTEMS

The evaluation of present system benefits is based entirely on questionnaire data (Appendix Exhibits B6 and B7, pages A41 and A60). This input is mostly subjective and is based on recollection. The variation in individual estimates is frequently large and occasionally extreme. The data presented thus must be regarded with a degree of skepticism. However, it is the contention of the study group that despite the weakness of the data noted above, the information shown is sufficiently valid to warrant acceptance as a provisional system benefit evaluation. The reason for this degree of confidence in the averages is based on the following considerations:

1. The method used to obtain data was designed to focus the respondents' attention to significant items in the evaluation of benefits, such as direct time savings, savings in equipment utilization, travel times, etc.

2. Comparisons of benefits using parallel questionnaire items show good agreement.

3. The costs of the telecommunications systems on the districts were not known to the questionnaire respondents and are not known generally. These were computed on the basis of considerations shown in the preceding section by the study members. However, the reported benefits bear a marked relationship to the cost figures.

1. NATURE OF STUDY SAMPLE

Questionnaires were distributed to rangers and staff on 63 districts in regions 1 through 9. With some exceptions, two districts each were selected on sample forests, representing an approximate 8% sample of districts in each region. The selection of both sample forests and sample districts was to some extent based on considerations of scope and type of functional activities. Forests with activities representative of the regions and districts with heavier workloads were chosen (Figure 2, page 62). The sample is thus a non-random one and is representative of telecommunication activities on average and above average workload districts (50% of all districts). This sample selection procedure was necessary to assure adequate data for analysis.

2. CONTRIBUTIONS TO NON-EMERGENCY MANAGEMENT ACTIVITIES

Benefits from radios associated with natural resource management and with district administration are generally related to direct time savings, equipment utilization savings, savings due to flexibility in manpower utilization and general operational efficiency. Questionnaire items 1 through 4 (Appendix, pages A43 through A48 and A61 through A66) in the District Ranger and District Staff questionnaires relate to these factors. Each respondent selected up to three activities representative of his major effort for detailed treatment (questionnaire item 2a). Item 4b in the District Ranger's questionnaire solicits information on the overall dollar benefits associated with each one of the three specific activities selected in item 2a (Appendix, pages A45 and A48).

To arrive at estimates of the overall contributions of radio telecommunications to the resource management activity on the sample districts, the various activities selected by the district ranger and his staff were assumed to provide a composite of activities for each sampled district. (This may have resulted in some underestimates of the total benefits from the use of radios.) If more than one respondent on the district selected the same activity, an average of the reported radio benefits was taken. In those cases where the presumably most knowledgeable and directly concerned respondent provided the input (mostly the district ranger for activities in which he was directly involved such as general administration, and the FCO for fire pre-suppression) this estimate only was used (Appendix Exhibit 10, page A87).

These averages are shown in Table 11, page 63. A notable aspect of this table is the magnitude of the contribution from non-emergency radio use (overall weighted average of $4,581 per district per year) when compared to the contributions from emergency radio uses ($3,721 fire pre-suppression and $1,368 safety).

The average district toll call saving estimates are based on responses to questionnaire item #5 in the district rangers' questionnaires.

Table 12, page 64 shows the estimated direct yearly time savings associated with the district activities on which the dollar benefit estimates were based. It can be seen that the direct time savings would yield somewhat higher benefits than those shown in Table 11 if multiplied by an average hourly wage rate.

3. CONTRIBUTIONS TO FIRE PRE-SUPPRESSION

The estimated contribution of radios to fire pre-suppression are shown in Tables 13 and 14, pages 65 and 66. The estimated monetary benefits range from a low of $785 per district per year in Region 9 to a high of $8,738 per district in Region 3. The latter average appears to be excessive by comparison with other regional averages. The overall weighted average for all regions is $3,721.

The estimated benefits shown in Table 13, are based on the direct time saving contributions shown in Table 14 and on increased manpower utilization efficiency during high fire danger days. The estimates may also include benefits due to potential resource savings which would, in turn, include the consideration of faster initial attack responses. Estimates of average time savings on initial fire attacks for an individual responding to a fire call are shown in the last column of Table 14. This figure thus represents the "speed up" of initial fire attack due to radio communications.

Estimates based primarily on responses by fire control officers (column 4 of Table 13) tended to be higher than estimates by other district personnel. Extreme benefit estimates were reduced to regional averages computed on the basis of all raw entries for each region.

4. CONTRIBUTIONS TO SAFETY

Of the 63 districts returning questionnaires, 58 or 94 percent indicated use of radios in emergency situations other than fire suppression. The emergencies ranged from very serious (threatened loss of life) to simple emergencies. The following categories for classification of reported emergency situations were used:

a. Reported instance of danger to life with the specific claim of saving of life.

b. Specific instances involving potentially disabling injury but no specific claim of danger to life.

c. Potentially injurious situations.

Apart from benefits connected with direct costs due to medical costs and compensation or, in the case of public aid, the social costs of care for family and insurance costs (based on number of fatalities or accidents among the insured), there are benefits in possibly shortening the rescue effort both through increased efficiency and through more efficient recall of crews. These additional benefits were absorbed in the total in order to err on the side of a conservative estimate.

Benefits associated with the availability of communications (telephone in a few instances) were evaluated separately for each type of case.

a. Danger to Life

The direct costs to the Government resulting from a Forest Service employee fatality in 1970 averaged $65,000 per case on the basis of BEC costs (Appendix Exhibit B9, page A79.) Social costs associated with fatal accidents are estimated variously at from $9,000 to $30,000, with some estimates in excess of these [1,4]. Using the higher estimate at about half the direct costs associated with Forest Service fatalities, a social cost of $33,000 per case for non-Forest Service employees will be used.

A residual cost to the Government can be assumed to exist even in the case of a successful rescue and hence, the actual loss figure used in case of life threatening hazards was $64,000 per case for Forest Service employees.

Frequency of Emergencies Involving Danger to Life. The number of emergency situations reported by the sample districts (edited for duplication) are shown in table 15, page 67. This table shows that one danger to life case involved a Forest Service employee and that there were seven additional cases involving the general public, all based on specific claims of saving of life.

Risk of Death. The risk of death in each case, without a rescue effort, will be assumed to have been 80% based on the specific claim of saving of life by the rescuers. This implies that in 20% of the cases death would not have resulted even without a rescue effort.

Effectiveness of Telecommunication. In the absence of intimate knowledge regarding the reported cases, a conservative estimate of 25% contribution of telecommunications to the over-all rescue effort will be made. This is based on indications of time savings and improvement in coordination in connection with the rescue efforts due to the availability of telecommunications.

Computation of Benefits Due to Telecommunications in Life Endangering Cases. On the basis of the estimated losses and the estimated risk of loss and telecommunication effectiveness, the benefits ascribable to telecommunications were calculated to be, per case:

Forest Service employee: $64,000 x (.8 x .25)
=$64,000 x 2
12,800 dollars per case

General public : $33,000 x (.8 x .25)
=$33,000 x .2
= 6,600 dollars per case

b. Disabling Injury

The losses associated with cases representing potentially disabling injuries were taken to be at the level of the average cost associated with such injuries in the Forest Service. The average direct cost per case was $760 in 1970, based on Bureau of Employee Compensation figures (Appendix B9). A potential loss of one-half of this amount was assumed to be associated with non-Forest Service cases (due to an increased demand for hospital beds, cost of absenteeism, insurance premium costs, etc.).

Risk of Disabling Injury. The actual risk of disabling injury in the absence of a successful rescue effort will be assumed to be 60 percent, in accordance with the less specific claims by the questionnaire respondents.

Effectiveness of Telecommunications. The contribution of telecommunications to the total effort will be assumed the same as in the previous case, 25 percent.

Computed Benefit Due to Telecommunications in Case of Potential disabling injury. The benefit per case is computed as:

Forest Service employee: $760 x .6 x .25
=$760 x .15
= 114 dollars per case
General public $380 x .6 x .25
=$380 x .15
= 57 dollars per case

c. Other Injuries

All emergency cases listed by the district staff and district rangers with no specific mention of serious injury were classed in this category. Hence this category includes potentially serious cases which, however, were not specifically labeled as such. A marginal benefit of eighteen dollars, corresponding to the average first aid costs incurred by the Government in cases of Forest Service employee first aid type of injury, was credited to this use of radio communications in these aid and rescue efforts.

d. Threatened Damage to Property

Where radio communications played a role in preventing property damage, a benefit estimate was made on the basis of the specific case. A benefit of 100 dollars each was credited to the use of radio communications in preventing a truck and a car fire. A benefit of 1,000 dollars was credited to the use of radio communications in case of a threatened power station.

e. Overall Safety Benefits

The overall sample district benefits per region, associated with availability of telecommunication in safety threatening situations, are shown in column 10 of table 15, page 67. The computed totals are based on the cases listed for each regions. The computation procedures used were those described above.

The last column of table 15 shows prorated district averages. The monetary benefits from this application of telecommunications are relatively small when compared to the contributions of radio communications to resource management and fire pre-suppression activities.

f. Relative Contributions to Overall Radio Benefits

The relative amounts of the contributions, by type of use, to the overall benefits derived from radio communication systems are of considerable interest. Using Service-wide averages, the computed radio use benefit per district per year is 9,670 dollars. Of this amount, an average of $3,840 is due to benefits associated with non-emergency forest management uses, an average of $740 is due to yearly savings in telephone toll charges per district, an average of $3,720 is due to benefits associated with fire pre-suppression radio uses and an average of $1,370 is related to the use of radios in safety threatening emergencies.

On a percentage basis, the breakdown is as follows:

Non-emergency forest management radio uses	39.7%
Telephone toll charge savings	7.6%
Fire pre-suppression radio uses	38.5%
Radio contributions to public and employee safety	14.2%

C. BENEFIT COST COMPARISONS

Table 16, page 68, shows three measures of benefit expressing the monetary contributions associated with the use of radio telecommunications:

1. Average yearly net benefits for the system

2. Benefit-cost ratios

3. Annual return on capital invested in the radio telecommunication systems

The three measures show substantial benefits associated with the use of the radio systems. The weighted Service-wide averages are perhaps the most indictive of the relationship of cost to benefits.

The average yearly district costs were computed on the basis of a listing of the hardware in the systems provided by the ranger for each sample district. This information was used in conjunction with average ownership costs per item of hardware (Table 17, page 69). The average cost per district is thus only an approximate expression of the real costs and does not include considerations of cost differences due to age of equipment or other special circumstances.

The average net benefit per district associated with the radio system is the difference between average system costs and average gross system benefits. Net benefits are an indication of the actual magnitude of the derived benefits but their significance must be evaluated against the system costs. (A $10 net benefit is highly significant on an investment of $30 but insignificant on an investment of $1,000; the actual magnitude of the net benefit is small in either case.) The average yearly district net benefits shown in Table 16 are of an order of magnitude comparable with average yearly system costs.

The benefit cost ratio is the ratio of gross yearly benefit and yearly system ownership cost. It expresses the amount of benefit per dollar of ownership cost and is therefore a suitable medium when comparing systems with widely differing costs. The overall, weighted benefit cost ratio for the sampled districts is 1.42; the unweighted overall benefit cost ratio is 1.38.

The amount of annual return is a percentage based on the net average district benefit divided by the total district radio system investment cost. In computing the net benefit for the purposes of this computation, the "opportunity interest" (interest on money which

could have been invested otherwise) was not included in the ownership cost, thus reducing this cost. The "return" represents the annual interest on the capital invested in the system. On this basis all regions show the radio system to represent a sound investment.

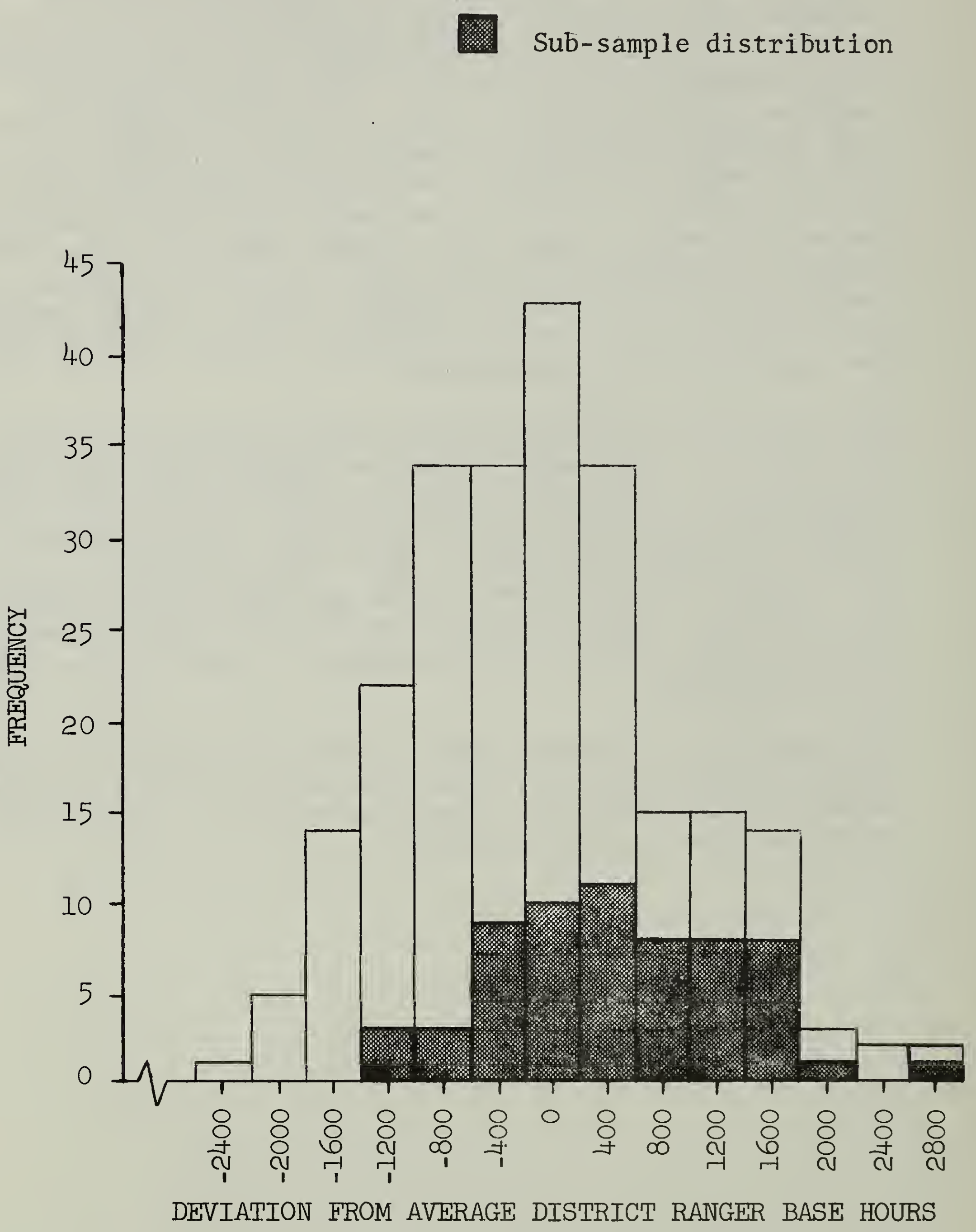
D. BENEFITS BY FUNCTIONAL AREA

Table 18 on page 70 summarizes the contributions from the use of radios in various forest management activities. The average yearly benefit estimates range from a low of $42 in wildlife construction and maintenance to a high of $2,542 in fire presuppression activities. The figures represent regional averages based on questionnaire estimates. Where the individual reported estimates clearly exceeded the general range of estimates, an overall average for the activity was substituted. Those few estimates which were clearly well below the general range were excluded from the count. The number of responses, and the number of edited responses, for each activity are shown in columns 1 and 2. Those benefits which are based on very few responses (fewer than 10) must be regarded as very preliminary.

The activities in Table 18 are listed in decreasing order of benefits. This order should be compared with the rangers' selection of activities deriving largest benefit from radio communications (Table 19, page 71) based on questionnaire item #6 (Appendix page A48). With a few exceptions, such as for example law enforcement, good agreement exists between the two orderings. The estimated benefits seem thus to reflect correctly the relative contributions of radios to the respective activities.

The benefits by function shown in Table 18 represent estimates based on those districts where such activities are an important aspect of the districts' overall activities. The estimates may therefore have a positive bias.

Figure 2. Distribution of the deviations from the average of district ranger base hours for all districts on thirty-three sampled forests and for a non-random subsample.*



* Non-random sample of 63 districts was subsampled from 238 districts on sampled forests.

Table 11. Average estimated sample district benefits (dollars) from the availability of radio communications in non-emergency forest management activities.

Region	Number Sample Districts	Av. District Management Benefits/yr. (dollars)	Av. District Toll Call Savings/yr. (dollars)	Av. District Non-emergency Benefit Total/yr. (dollars)
1	8	2,642	559	3,201
2	8	4,108	489	4,597
3	5	2,053	632	2,685
4	8	2,009	538	2,547
5	8	6,181	1,575	7,756
6	10	4,682	1,166	5,848
8	8	4,931	408	5,339
9	7	3,166	350	3,516
Overall weighted average	62	3,842	739	4,581

Table 12. Average estimated direct time savings per district due to the availability of radio communications, non-emergency forest management activities.

Region	No. Sample Districts	Av. No. Employees Per District		Av. Direct Time Savings (Hours Per District Per Year)		
		PFT	Peak Temp.	D.R. + Staff	Crews	Total
1	8	11	35	246	149	395
2	8	6	18	194	159	353
3	6	10	21	219	336	555
4	8	6	26	260	417	677
5	8	19	41	176	966	1,142
6	10	28	35	401	1,113	1,514
8	8	15	14	376	485	861
9	7	9	20	266	290	556

Table 13. Average fire pre-suppression benefits for districts due to availability of radio communications.

Region	Number Sample Districts	Fire Pre-suppression Benefits, general av. (dollars per year)	Fire Pre-suppression Benefits, av. based primarily on FCO's (dollars per year)*	Difference (dollars per year)
1	4	4,392	5,515	1,123
2	4	2,461	3,710	1,249
3	4	3,119	8,738	5,619
4	4	2,929	4,400	1,471
5	5	2,807	3,725	918
6	7	2,317	3,207	890
8	7	1,612	2,060	448
9	5	1,507	785	-722
Overall weighted average	40	2,517	3,721	1,204

*High individual estimates indicate that potential value of resource losses was included in some estimates.

Table 14. Estimated direct fire pre-suppression time savings and initial fire attack time savings per district.

Region	Pre-Suppression Direct Time Savings Per Dist. (hrs./yr.)			Initial Attack Time Savings (hrs./dist.)	
	D.R. + Staff	Crews	Total	Per Year	Per Fire
1	83	92	175	28	2.6
2	182	422	604	35	2.1
3	103	401	504	24	1.8
4	138	255	393	27	1.5
5	113	940	1,053	61	1.7
6	435	1,086	1,521	66	2.5
8	45	87	132	77	1.6
9	43	30	73	52	1.4

Table 15. Number of emergencies and estimated emergency radio use benefits on sample districts in 1970

Region	No. Sample Dists.	Frequency of Injury Cases: Life Threat Injury FS	Life Threat Injury NFS	Possible Disabling Injury FS	Possible Disabling Injury NFS	Other Type Injury FS	Other Type Injury NFS	Property Damage	Total Computed Emergency Use Benefits for All Sample Dists. in Region (Dollars)	Average Benefit Per Dist. (Dollars)
1	8	0	1	8	3	8	25	1	8,477	1,047
2	8	0	0	0	3	0	20	0	1,531	66
3	6	0	0	2	3	1	15	0	687	137
4	8	0	2	3	9	0	35	2	14,685	1,836
5	8	0	2	0	17	19	145	0	17,121	2,140
6	10	1	1	64*	12	7	185	1	31,163	3,114
8	8	0	1	0	9	5	17	0	7,509	939
9	7	0	0	0	9	3	117	1	3,673	525
Service Wide	62	1	7	77	65	43	559	5	84,846	1,368

*Includes a 54 man crew.

Note: FS means Forest Service Employee and
NFS means Non-Forest Service Employee.

Table 16. District radio ownership cost versus benefits for sixty-two sampled districts

Region	Number Sample Districts	Av. Yearly District Costs $	Av. Yearly District Benefits* $	Av. Yearly District Net Benefit ($)	Benefit Cost Ratio	% Annual Return on Invested Dollar
1	8	7494	9,763	2,269	1.30	17.98
2	8	3888	8,373	4,485	2.15**	46.26
3	5	5757	11,560***	5,803	2.01	44.21
4	8	7143	8,783	1,640	1.23	15.29
5	8	11,289	13,621	2,332	1.21	16.08
6	10	7204	12,169	4,965	1.69	28.11
8	8	7291	8,338	1,047	1.14	12.66
9	7	3874	4,826	952	1.25	13.97
Overall weighted average	62	6,852	9,747	2,895	1.42	23.65

*Includes Fire Pre-Suppression Benefits based primarily on FCO'S estimates.

**Due to low computed average System Cost.

***Due to high estimated Fire Pre-Suppression Benefits.

Table 17. Average district system ownership cost computations

Equipment	Reg. 1		Reg. 2		Reg. 3		Reg. 4		Reg. 5		Reg. 6		Reg. 8		Reg. 9	
	No.*	Cost**	No.	Cost	No.	Cost	No.	Cost	No.	Cost	No.	Cost	No.	Cost	No.	Cost
Mobiles	39	261	29	256	23	258	31	367	69	309	70	181	63	258	35	190
Portables, light	24	184	19	183	15	184	30	268	45	223	63	162	30	184	26	156
Portables, heavy	56	311	9	310	36	312	15	384	23	364	54	204	26	312	20	173
Fixed Base Stns.	15	615	8	608	7	611	16	620	10	705	8	738	24	611	14	461
Links, Repeaters, ac, Repeaters, batt. ***	9	948	7	970	3	985	20	952	7	1047	8	1070	5	863	6	917
Remotes	17	100	11	100	13	100	8	100	15	100	9	100	16	100	3	100
CB's	0	12	0	12	0	12	1	12	6	12	24	12	2	12	3	12
No. Sample Districts	7		7		5		8		5		7		7		7	
Av. Cost Per Sample Dist./yr	$7494		$3888		$5757		$7143		$11289		$7204		$7291		$3874	

* Number of pieces of given type of equipment in sample districts in region.

** Yearly ownership Cost per item of equipment in region (dollars)

*** $110 constant cost was used for each repeater and link structure (does not appear in table cost figure).

Table 18. Average regional benefits per district per year (Dollars) by functional activities
(Based on estimates by all questionnaire respondents and edited for extremes.*)

Activities	Number Respondents	No. Edited Respondents	R-1	R-2	R-3	R-4	R-5	R-6	R-8	R-9	Overall Average
Fire Pre-Supp.	69	10	4392	2461	3119	2929	2807	2317	1612	1507	2542
Adm. of Wilderness	5	1	----	150	----	1250	800	500	----	5450	1630
Range Revegetation	6	1	----	----	900	158	3499	----	200	----	1189
Timber Sales Adm.	50	3	200	600	1577	450	2075	1448	849	581	973
General Adm.	87	2	463	1064	609	190	2543	844	828	893	929
Rec. OP. and Mtc.	49	0	600	1760	474	484	1507	180	1460	340	851
Insect & Dis. Contr.	8	0	----	92	0	----	----	300	2500	----	723
Range Structures	7	0	1500	1000	30	280	----	----	----	----	702
Constr. & Pre-Const. of Roads & Trails	19	0	1000	383	----	533	212	856	----	----	597
Roads & Trails Mtc.	22	0	400	312	150	233	535	287	1715	500	517
Reforestation	7	0	850	----	----	20	500	----	500	400	454
Law Enforcement	64	2	332	550	775	428	763	135	343	213	442
T. S. I.	15	1	842	200	200	15	600	----	412	240	359
Timber Sales Prep.	29	1	100	160	600	212	600	298	658	218	356
Range Analysis	12	0	1200	217	83	100	----	100	30	----	288
Land Uses	61	1	210	566	400	162	364	189	200	179	284
Timber Surveys	9	0	50	----	500	5	200	175	52	----	164
Rec. Dev.	3	0	200	----	----	----	50	250	----	----	167
Wildlife Inv.	14	0	10	200	50	175	----	100	225	50	116
C & M of Adm. Imp.	2	0	----	----	----	200	20	----	----	----	110
Watershed Inv.	3	0	----	0	0	200	----	----	----	----	67
Wildlife C & M	2	0	----	----	85	----	----	----	----	0	42

* Data well outside the range of the bulk of the data.

Table 19. District Rangers' rating of activities deriving greatest benefits from radio communications.

Activity	No. Times Activity Selected	Computed* Overall Rating
Fire Suppression	53	1.4
Search and Rescue	4	3.7
General Administration	42	3.9
Timber Sales Administration	40	4.0
Recreation Operation and Maintenance	48	4.2
Engineering and Range Structure	9	4.5
Law Enforcement	26	4.8
Range Revegatation	5	5.0
Slash Disposal	7	5.1
Timber Stand Improvement	11	5.3
Wilderness Administration	11	5.5
Roads and Trails: Construction and Maintenance	35	5.6
Recreation Development	6	6.0
Range Analysis	19	6.2
Timber Sales Preparation	12	6.5
Minerals Management	4	6.7
Project Administration	5	6.8
Reforestation	17	7.1
Watershed Restoration	5	7.2
Insect and Disease Control	5	8.4
Wildlife Improvement	1	9.0
Construction and Maintenance of Administrative Improvements	2	10.0
Watershed Improvements	5	10.0
External Cooperations	1	11.0

* Computed Overall Rating =
sum of (D.R. ranks x frequency of rank)/(no. times selected)

PART III

EQUIPMENT REPLACEMENT AND MAINTENANCE POLICY EVALUATION

A. RADIO COMMUNICATIONS EQUIPMENT REPLACEMENT ANALYSIS

The objective of this analysis was to determine the optimal equipment "lifetime" (i.e., the time period between replacements which results in the lowest total cost) for each type of radio communications equipment (i.e., fixed station, mobile or portable).

Field data relating to this objective were gathered as follows:

a. Each regional electronics engineer was requested to categorize his equipment according to 25 pre-defined categories. A Regional Equipment Inventory form was used for this task.

b. Sample Forests were selected on the basis of the completed Regional Equipment Inventory forms (Appendix Table A6). An attempt was made to avoid inherent biases (e.g., regional policies, environmental differences, operational differences) by choosing a good cross-section.

c. Selected Forests were informed of the specific categories of equipment to be sampled and the corresponding quantity within each category. The Maintenance Data Form (completed by the Forest technician) requested information on equipment purchase date and a historical summary of all equipment maintenance (including maintenance dates, types, bench-time, and parts cost) performed during the equipment lifetime.

Statistically significant historical maintenance data could only be obtained from equipment with a range of ages from one to fifteen.

A prerequisite for determining a standard for equipment replacement is the development of a replacement rationale. Why should radio communications equipment be replaced? The following factors were investigated because they were presumed to have a significant potential influence on radio replacement.

1) Effect of Equipment Age on Breakdown Rate. If equipment breakdown rate increases with age and reaches an unacceptable level, then replacement is warranted. Related to this rationale is:

2) Effect of Increasing Equipment Age on Maintenance Costs. A primary argument for equipment replacement is frequently the contention that maintenance costs reach uneconomical proportions when equipment gets "old".

Related to equipment age indirectly through the rate of technological progress is the third factor which will be considered in replacement of radio equipment.

3) Obsolescence Cost. These costs are due to the potential differences between aging equipment and new state-of-the-art equipment caused by technological innovations. These differences may produce:

   a. Labor savings due to more efficient operation of new equipment.

   b. Operational savings due to decreased installation costs, power efficiency, etc.

   c. Maintenance savings due to lower breakdown rate and easier component replacement in new equipment.

In the subsequent sections the above factors will be analyzed in detail.

1. EFFECT OF EQUIPMENT AGE ON BREAKDOWN RATE

Data gathered from equipment maintenance histories were analyzed to determine how break-down rates vary with equipment age. Equipment was categorized into six types

Fixed station (tube)

Fixed station (solid state)

Mobile (tube)

Mobile (tube)

Portable (tube or partially transistorized)

Portable (solid state)

The average number of breakdowns per year for each age of equipment lifetime was calculated for each type of equipment. A Multiple Regression Analysis technique was used to construct a relationship of average number of breakdowns per year as a function of equipment age. The regression functions and actual data points for all six types of equipment are shown in Figure 3, page 90. The functions cover a range of equipment age extending from one to fifteen years.

Notice that for each type of equipment, the highest yearly average breakdown rate is always well below the regional average acceptable breakdown rate specified by the regional electronics engineers in Table 20, page 91.

Therefore, the breakdown rate of old (i.e., 10-15 years of age) equipment does not exceed acceptable tolerances. Consequently it is not an influential factor in determing replacement cycles when viewed as an individual entity.

2. EFFECT ON INCREASING EQUIPMENT AGE ON MAINTENANCE COSTS

The available maintenance costs were separated into fixed costs (i.e.,costs which do not vary with equipment age such as test equipment and cost associated with preventive maintenance) and variable costs. Variable costs were defined as:

a. Labor costs associated with breakdown maintenance.

b. Parts costs associated with breakdown maintenance.

Historical maintenance data were used to calculate average service time and average parts cost per breakdown maintenance for each age of equipment lifetime for every equipment type.

Linear regression analysis was used to derive relationships of average service time per breakdown and average parts costs per breakdown as functions of equipment age. The regression functions and actual data points are shown in Figures 4 and 5 on pages 92,93.

A careful perusal of the functions indicates a general trend of little variation of parts costs or service time per breakdown as equipment ages.

The individual variable maintenance costs were combined to create a single variable annual maintenance cost function of equipment age. The regression functions shown in Figures 3, 4, and 5 were combined in the following way:

Variable Annual Maintenance Cost (Age)=

[ave. breakdowns/yr. (age)]x[(ave. service time/breakdown (age) +2 hrs. travel time)x($5.50 (hr.) + ave. parts cost/ breakdown (age)]

The variable annual maintenance cost as a function of equipment age was derived from the above formula for each type of equipment and is shown in Figure 6 on page 94.

Notice that in no case is the variation in variable annual maintenance costs greater than thirty dollars per year. In addition, there is no trend indicating a rapid rise in maintenance costs as equipment

reaches old age (10-15) years). Hence, the factor of increasing maintenance costs with increases in equipment age is insignificant when viewed as a separate entity.

3. OBSOLESCENCE COSTS

Direct obsolescence costs of 1960 type equipment, compared with 1970 equipment, have been identified (Appendix Exhibit B11, pages A88-A98) as follows:

a. Portable Radios (comparison based on 1960 P 33's and 1970 PT-300, PT-400's):

   1) Higher battery costs of older equipment..............................$64.35/radio/year

   2) Differences in breakdown/maintenance costs..................................$2.50/radio/year

b. Mobile Radios (comparison based on 1960 "TWIN V" and 1970 MOTRAC):

   1) Greater gas consumption requirements of older equipment...................$47.00/radio/year

   2) Differences in maintenance costs,....$12.00/radio/year

   3) Prorated installation cost differences..........................$30.00/radio/year

c. Fixed Stations

   1) Greater power consumption requirements of older equipment......................$33.75/station/year

   2) Differences in maintenance costs.....$20.00/station/year

Based on the above, the direct obsolescence costs of a composite unit based on the proportion of portable (.5410), mobile (.3014) and fixed stations (.1575) in use in the Forest Service is:

$66.90 x (.5410) + $89.00 x (.3015) + $55.75 x (.1575)= 71.78 dollars per composite unit per year.

The above direct obsolescence costs do not include costs incurred when new technologies provide opportunities (unexploited) for increased productivity. In the evaluation of alternative replacement policies, Table 21, pages 95 through 97, obsolescence cost levels of \$105 and \$140 were used to incorporate productivity increases. Table 21 shows the total yearly costs to the Forest Service associated with various replacement policies (replacement after 5 years through replacement after 19 years), based on a total of 22,000 units in use in the Forest Service and the distribution between types of equipment shown earlier (page 73). Yearly costs include purchase costs (without interest), age related maintenance costs (not related to redesign or innovation), and obsolescence costs. Calculations assume that under any policy only a proportionate part of the Forest Service equipment would be replaced in any one year (e.g., one fifth of all equipment replaced if a five year replacement policy were in force, one tenth if a ten year policy were adopted, etc). Under this (realistic) assumption, a linear rate of increase for obsolescence costs may be used. (The full obsolescence cost of \$70, \$105 or \$140 is reached over the duration of a technological cycle -- the time between breakthroughs -- of approximately ten years).

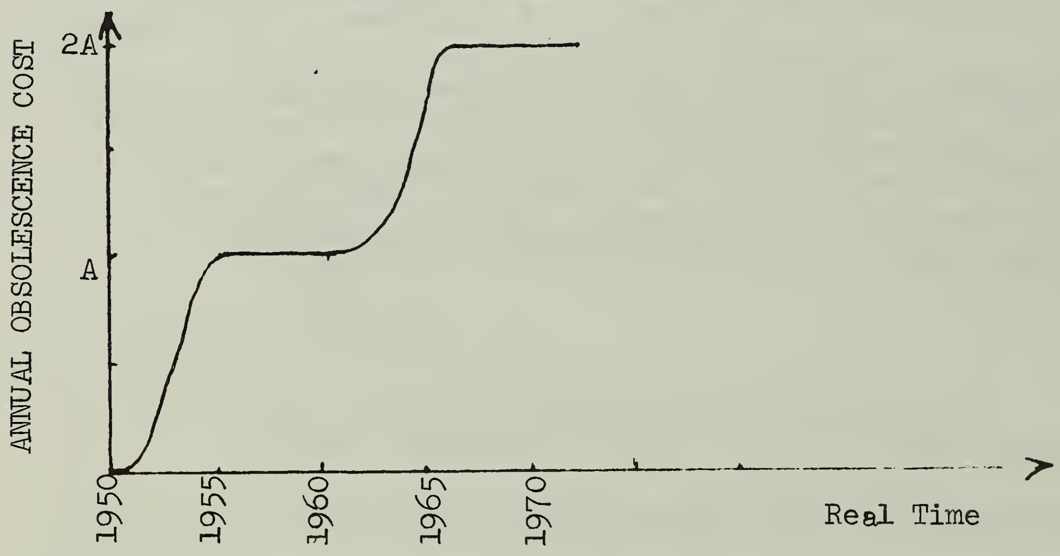
Table 21 shows that small departures from the optimum replacement policy produce relatively unimportant increases in total costs. Replacement of Forest Service radio communications equipment at ten to twelve year intervals would thus best minimize the total Forest Service communications costs for the entire range of obsolescence costs.

4. OBSOLESCENCE MODEL

Technological innovations which have significant ramifications in improving equipment efficiency are called "breakthroughs." Radio communications equipment has exhibited a cyclical trend for "breakthrough" occurrence with "breakthroughs" appearing on ten-year increments [2]. The technological cycle has also been influenced by the fact that cost benefits attributable to "breakthroughs" have risen rapidly in the five years immediately following the occurrence, and leveled off to a constant value until the next "breakthrough" (i.e. remain constant for the last five years of the cycle). In other words, the cost benefits of the technical innovation are totally realized after a five year period.

An example of an annual obsolescence cost functions (for a piece of radio communications equipment purchased in 1950) is shown in Figure 7, (below) for illustrative purposes.

Figure 7. Annual obsolescence cost function for equipment purchased in 1950.

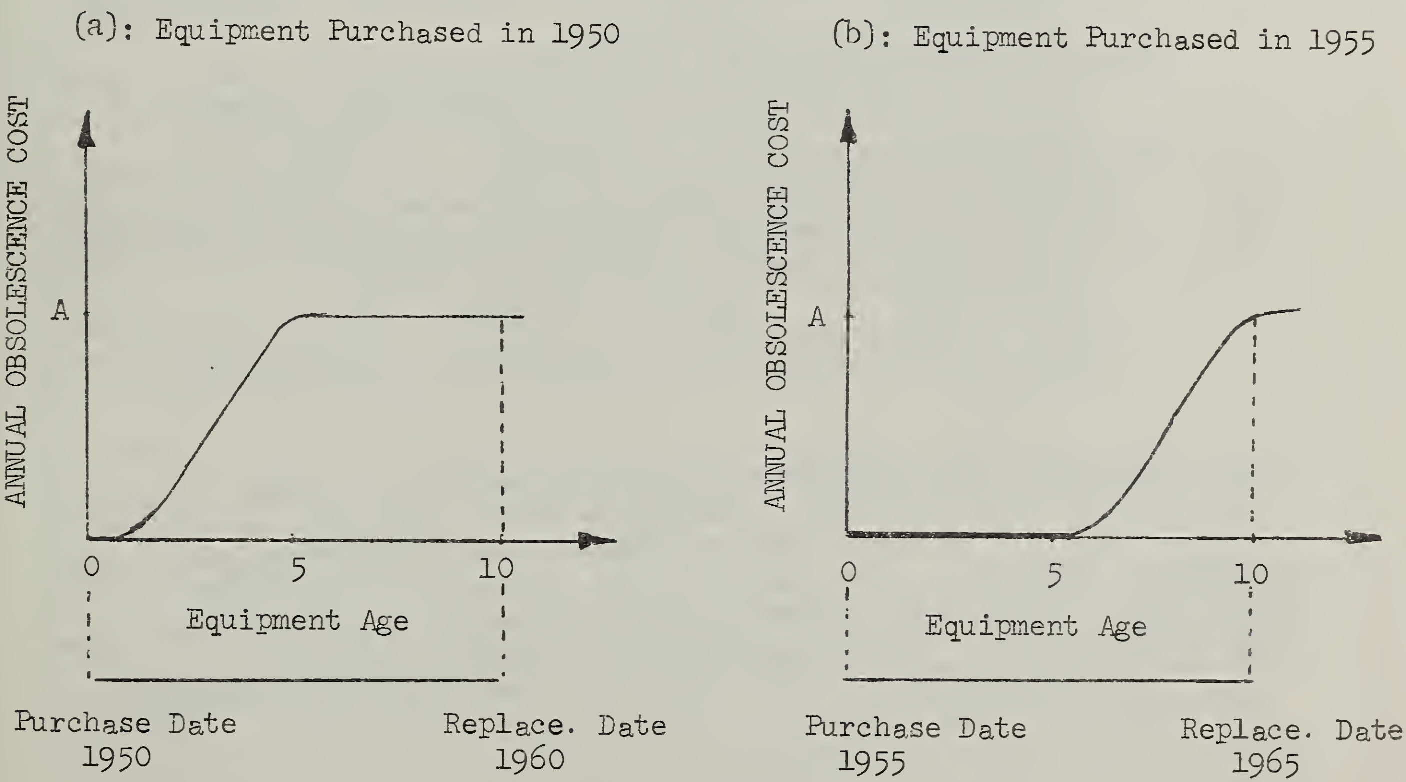


Notice that the amplitude of the annual obsolescence cost function (A) is undefined. The obsolescence costs, mentioned previously are seldom quantifiable and are more suitable for treatment in a parametric analysis, where A is varied over a range of values. Also note that the same amplitude is assumed for each cyclical portion of the function. This is a conservative approach (i.e. new cost benefits attributable to technological advances occur at a constant rate).

The essential point to recognize is that the annual obsolescence cost function for a piece of equipment is a function of <u>both equipment age</u> and <u>the year of purchase</u> (i.e. year relative to the start of a new technological cycle).

To illustrate this point, suppose one piece of radio communications equipment was purchased in 1950. It faced the annual obsolescence cost function shown in Figure 8a, below. During the year of purchase a "breakthrough" occurred, causing the equipment to "age" rapidly during the first five years of existence (i.e. cost benefit comparisons of this piece of equipment with new equipment which incorporated the technological "breakthrough" rose rapidly). After five years (equipment was 5 years old) no additional benefits of the "breakthrough" were realized during the next five years. In 1970 (equipment age = 10); the next "breakthrough" occurred and the cycle began again. Figure 8b below shows the obsolescence cost function of a piece of radio communications equipment purchased in 1955. From the year of purchase until 1960 (equipment age = 5), no cost benefits were derived from the 1950 "breakthrough". In 1960, another "breakthrough" occurred which caused the obsolescence cost function to rise rapidly until 1965 (equipment age = 10).

Figure 8. Obsolescence cost functions of radio equipment with two different purchase dates



Since annual obsolescence cost is a function of both equipment age and real time, the point within a technological cycle when a replacement occurs has a great deal of influence on the annual obsolescence costs which the new equipment will face. Therefore, it is economical to replace equipment during a year where the new equipment will face a zero annual obsolescence cost as long as possible. It is unwise to

replace a piece of equipment near the time of a technological "break-through", because the equipment will become obsolete at a highly rapid rate.

Each time a piece of equipment is replaced, it faces a new annual obsolescence cost function of equipment age which is dependent on the replacement year (see Figure 8, page 79). Hence, in order to create the new annual obsolescence cost function from the original function (which the equipment faced during the first year of the analysis), a transformation routine was derived. The essence of the routine is to shift the frame of reference on the original function to the point designated by the relative year (within a technological cycle) when the equipment is replaced. The details of the transformation are given in the Appendix Exhibit B12, page A99.

Significant Model Parameters

The following parameters contribute to the cost of purchasing and maintaining a piece of radio equipment:

1) Purchase cost (PC): the amount of capital necessary to purchase a new piece of equipment at the present time.
2) Salvage value (SV[AGE]): the amount of capital which can be recovered when the equipment is "traded in." Salvage value is dependent on equipment age.
3) Annual Maintenance Cost (AMC[AGE]): the yearly labor, parts, and travel costs associated with maintaining the equipment. Annual maintenance cost is dependent on equipment age.
4) Annual Obsolescence cost (AOC [AGE]): the difference between costs associated with equipment of present age and new "state-of-the-art" equipment. Annual obsolescence cost is dependent on equipment age and the technological cycle.
5) Interest rate (I): the "cost of money." This is the annual rate of return that could be expected if the money which is spent on the equipment is invested for a profit or must be borrowed.

Purchase costs were taken from the average prices for fixed, mobile, and portable radios in 1971. Salvage value as a function of equipment age was derived for fixed station, mobile, and portable equipment (see Figure 9, page 98). The functions were based on the percentage of purchase cost which was allowed on trade in equipment of different ages (according to the Federal Supply Schedule Catalog and Price List). The derivation of annual maintenance costs were previously described (see Figure 6, page 94).

5. DYNAMIC PROGRAMMING REPLACEMENT MODEL

A dynamic programming replacement model was formulated and programmed (in FORTRAN) in order to evaluate the combined effect of the previously mentioned parameters on costs associated with different replacement policies.

Specifically, the model was created to assist in the selection of a replacement policy which yields the lowest total cost for operating and maintaining a piece of radio communications equipment over a specified time period.

A replacement policy consists of a sequence of Annual Decisions to "Replace" or "Keep" the equipment at the end of each year. There is a cost associated with each Annual Decision. The Annual Decision cost is always dependent on the age of the equipment during the year that the decision is made.

If the annual decision is "Replace", then the Annual Decision cost (ADC) will be the purchase cost minus the salvage value plus the annual maintenance cost (AMC) and annual obsolescence cost (AOC) of operating the equipment during its first year of existence. The resulting formula is:

Annual "Replace" Decision cost (age=n)= PC-SV(age=n) + AMC (age=1) + AOC (age=1).

If the Annual Decision is "Keep", then the Annual Decision cost will be the annual maintenance cost plus the annual obsolescence cost of operating the equipment at an age equal to its present age plus one year. (i.e. the next year of equipment operation.) The resulting formula is:

Annual "Keep" Decision cost (age=n)= AMC (age=n + 1) + AOC (age=n+1).

Remember that a replacement policy is a <u>sequence</u> of Annual Decision costs. Therefore, the combination of Annual Decision costs which yields the lowest total cost over a specified time period will be chosen (i.e. an Optimal Replacement Policy). The total cost is the sum of the Annual Decision costs, which are chosen by the selected Replacement Policy (and also includes the "cost of money" specified by the interest rule). The Dynamic Programming Replacement Model evaluates all possible Annual Decision sequences; calculates the associated total costs; systematically eliminates non-optimal policies; and finally selects the Optimal Replacement Policy (the replacement policy with the lowest total cost) and calculates the corresponding total cost. This is done for a specified time period.

To illustrate the operation of the model, the various decision sequences may be visualized as a decision network (see Figure 10, page 99). Each node of the network represents a "state" in which the equipment is in (i.e. an age/year combination). Each link between nodes represents an Annual Decision (i.e. "Replace" or "Keep") which has been made to get from one "state" to another. For purpose of

illustration, a time period of four years has been chosen and one Replacement Policy and its associated total cost has been selected at random.

The model was programmed with the constraint that the maximum age before replacement is fifteen years. This was done to avoid unnecessarily lengthy computations and the definition of input functions based on no field data (since field data only exists for equipment up to fifteen years old).

The model inputs are:

1) Equipment Purchase Price
2) Salvage Value as a function of Equipment Age
3) Annual Maintenance Cost as a function of Equipment Age
4) Annual Obsolescence Cost as a function of Equipment Age
5) Interest Rate
6) Time Period for Analysis

The model outputs are:

1) Optimal Replacement Policy (i.e. years in which "Replace" is the optimal Annual Decision).
2) Optimal Replacement Policy Cost.

Derivation of Optimal Replacement Policies for Fixed, Mobile and Portable Equipment.

It was desirable to determine if the Optimal Replacement Policy changed as the following parameters were varied:

1) Time Period--number of years over which Replacement Policies were analyzed.
2) Initial Starting Point in Obsolescence Cycle--point within the Technological Cycle when the analysis began.
3) Amplitude of the Obsolescence Cost Function--the anticipated labor savings (both user and maintenance) between ten year old equipment and new equipment

The results of the parametric analysis were as follows:

1) Changing the Time Period did not alter the Optimal Replacement Policy
2) Changing the Initial Starting Point in the Technological Cycle did alter the specific years for Replacement but did not alter the number of years between replacements (i.e. the replacement cycle)
3) The Optimal Replacement Policy was plotted as a function of the anticipated man-hour savings due to the difference between new and ten year old equipment attributable to obsolescence (i.e. Amplitude of the Annual Obsolescence Cost Function). The results are shown in Figure 11, page 100. Notice that a ten year Optimal Replacement Policy is indicated for Fixed Station, Mobile, and Portable radios along almost the entire range of Annual Obsolescence Curve Amplitudes.

It should be noted that the use of an Annual Obsolescence Curve which increases (in cyclical fashion) at the same rate is a conservative approach since future technological advances will probably occur at an increasing rate. Consequently, the recommendation of ten year replacement cycles for radio communications equipment is a conservative estimate.

An analysis of Figure 11 shows that a savings of $105 per year between new and ten year old equipment is needed to justify a ten-year Replacement Policy for Fixed, Mobile, and Portable equipment when all equipment is replaced at the same favorable time period within the technological cycle.

Finally, the analysis emphasized the fact that obsolescence costs are the dominant factor for replacement and that age variable maintenance costs are relatively insignificant.

B. PREVENTIVE MAINTENANCE EFFECTIVENESS ANALYSIS

The purpose of this analysis was to determine the most economical frequency of performing preventive maintenance on Forest Service radio communications equipment.

The methodology was divided into a set of sequential stages. First, the factors relevant to preventive maintenance costs and benefits were defined. Next, the factors were researched and appropriate interrelationships were explored. The next stage consisted of collecting and statistically reducing historical field maintenance data. The reduced statistical data were used to verify the factor interrelationships previously explored. Finally, a GPSS Forest Maintenance Simulation Program was constructed and used to determine the cost/benefits of using different preventive maintenance policies (Appendix Exhibits B13 and B14 pages A100 - A114).

For purposes of analysis, all equipment was divided into six types:

1) Fixed Station -- tube
2) Fixed Station -- substantially transistorized
3) Mobile -- tube
4) Mobile -- substantially transistorized
5) Portable -- tube or partially transistorized
6) Portable -- solid state

Terminology

The following terminology is used throughout the analysis and should be interpreted in the following context:

Breakdown Maintenance - maintenance which is performed after an equipment failure.

Preventive Maintenance - periodically scheduled maintenance which is performed on equipment which is fully operational with the intent of lowering the probability of future equipment failure.

Equipment Downtime - time period corresponding to equipment in an "off-line" or non-functional status.

Service Time - technician time required to perform maintenance service on equipment.

Travel Time - time required by technician to travel to and from equipment location.

Equipment Availability - percentage of potential working time when equipment is operational (i.e., not in a "down" state).

Technician Utilization - percentage of technician's total working time that is spent servicing equipment and traveling to service equipment.

Time to Next Failure Distribution - a statistical probability distribution which gives the probability of equipment failure after a specified time period which begins at the completion of a breakdown or preventive maintenance.

Field Data

The data collection methodology, sample, and questionnaires were identical to those used in the equipment replacement analysis. However, an additional questionnaire (Travel Time Data Sheet) was sent to the Forest Supervisors for the purpose of enumerating the distances between all district headquarters, the Supervisor's office and the electronics technician's shop.

The questionnaire also provided total annual cost figures to check against analysis results. The format of the Travel Time Data Sheet may be seen in Appendix B8, page A78. The raw data which was acquired for each piece of equipment was:

1) Dates when Breakdown Maintenance was performed.
2) Dates when Preventive Maintenance was performed.
3) Maintenance Service Time for each Breakdown and Preventive Maintenance.
4) Maintenance Parts Cost for each Breakdown and Preventive Maintenance.

Rationale for performing preventive maintenance

The two possible effects of preventive maintenance on the Time to Next Failure Probability Distributions are:

- Equipment faces different Time to Next Failure Probability Distributions after completion of Preventive Maintenance and Breakdown Maintenance. The expected time until the next failure is greater after the completion of Preventive Maintenance than after the completion of Breakdown Maintenance.

- Equipment faces identical Time to Next Failure Distribution after completion of Preventive Maintenance and Breakdown Maintenance.

If there is an increase in the expected value of the Time to Next Failure Probability Distribution after the completion of preventive maintenance (i.e. the first condition holds), then the following rationale is relevant. The performance of preventive maintenance at appropriately spaced intervals is likely to reduce the maintenance rate since the expected time to the next failure is greater after a preventive maintenance than after a breakdown maintenance. Consequently, preventive maintenances could be substituted for a larger number of breakdown maintenances over a fixed period of time. Another benefit of preventive maintenance is the high probability that service times and "downtimes" for preventive maintenance are less than those associated with breakdown maintenance. Therefore, the performance of preventive maintenance would decrease the number of maintenances and the service

time per maintenance which, in turn, would decrease the technician utilization and increase the equipment availability.

The analysis proceeded by testing the following hypotheses:

1) A piece of communications equipment faces identical Time to Next Failure Probability Distributions after completion of Breakdown and Preventive Maintenance.
2) The Time to Next Failure Distribution is an Exponential Probability Distribution.

Hypotheses 1 was derived from field experience. The essence of the assumption is that radio equipment is brought to the same "level" after a breakdown maintenance as it is after a preventive maintenance. Consequently, it is equally likely to fail after a specified time period which is initiated after either type of maintenance. The fact that equipment is checked to insure operation within the same specified tolerances after completion of either type of maintenance adds credence to this assumption.

There is a strong theoretical precedent for the second assumption. In his text, Reliability Engineering [3], Von Alven states, "equipment with many parts which have many different failure patterns will indeed have a time-to-failure density closely approximated by an exponential." Many other references use the Exponential to describe time between failure distributions for electronic equipment.

The two hypotheses, when established, from the following proposition:

> CHANGES IN PREVENTIVE MAINTENANCE SCHEDULES FOR RADIO COMMUNICATIONS EQUIPMENT DO NOT ALTER THE EXPECTED BREAKDOWN RATE (I.E. MEAN TIME BETWEEN FAILURES).

This derives from the following rationale. The exponential probability distribution has a unique characteristic--it is "memoryless." Applied to the Time to Next Failure Distribution, this has the following significance: Equipment which is interrupted by a preventive maintenance after any time period will face a Time to Next Failure Probability Distribution which is identical to that which it would have faced if it were not interrupted.

Data reduction

The raw data mentioned earlier were reduced by formulating frequency histograms; fitting the histograms to probability distributions; and checking the validity of the probability distributions using the Chi-squared Goodness of Fit test.

The final form of the reduced data was as follows:

1) Time Between Failure Probability Distributions as a Function of Preventive Maintenance Schedule (see Figures 12, 13, 14, pages 101-103).

2) Breakdown and Preventive Maintenance Service Time Distributions (see Figure 15, page 104.)

It should be noted that Time to Next Failure Probability Distributions could not be derived from the raw data due to an inherent bias in the data. All equipment which was analyzed had at least one preventive maintenance per year. Therefore, preventive maintenances consistently interrupted the time period between breakdowns. Consequently, only those times between maintenance and breakdown which happened to be less than the time span between Preventive Maintenances were available for analysis. No data could be obtained on equipment which had undergone no preventive maintenance.

Forest maintenance simulation model

A GPSS Forest Maintenance Simulation model was created in order to observe the effects of different preventive maintenance policies on the radio communications operation on a Forest. The computer program and corresponding flow chart appear in Appendices B12 and B13. The model simulates the yearly occurrence of equipment breakdowns and corresponding travel and servicing functions of the Forest Technician. The travel and service times associated with preventive maintenance are also included.

Probability distributions were used to determine the time between failures and the service times for each piece of equipment.

The model inputs are:

1) Number of Forest technicians
2) Distances between district headquarters
3) Number of pieces of radio equipment of each type located in each Forest district
4) Time period for simulation

The pertinent simulation outputs are:

1) Total travel time for each technician
2) Total Breakdown Maintenance Service Time for each technician
3) Total Preventive Maintenance Service Time for each technician
4) Equipment non-availability (in terms of percentage) by equipment type (i.e., fixed station, mobile, and portable)
5) Technician Utilization--percentage of total available working time which technician uses for servicing equipment and traveling to perform maintenance.

Results of analysis

The statistical techniques and the GPSS Forest Maintenance Simulation Model were used as analysis tools to derive an optimal preventive maintenance schedule. The statistical techniques were used to prove hypotheses derived earlier. The simulation was used to develop cost/benefit relationships of various Preventive Maintenance policies.

Supportive evidence for hypotheses

If the postulated hypotheses (page 86) are true, then the Preventive Maintenance Schedule should have no effect on the Time Between Breakdown Probability Distribution.

The Time Between Breakdown Probability Distributions for all types of radio equipment are shown in Figures 12, 13, and 14 on pages 101-103. Notice that the actual probabilities (derived from raw data) are plotted for preventive maintenance schedules of once and twice per year. A single exponential probability distribution has been fitted to both curves (i.e., both for one and two preventive maintenances per year) within the acceptable tolerance of a Chi-squared Goodness of Fit test (with a 95% level of confidence). This was the case for all types of equipment.

Consequently the Time Between Breakdowns Probability Distribution has been shown to be identical for various preventive maintenance schedules and to be of the exponential form.

Notice that these results hold without exception for all six types of radio communication equipment. This is strong supportive evidence for the contention that preventive maintenance does not alter the breakdown rate.

It should be noted that data were not available on equipment which had no preventive maintenance. Consequently, no comparison could be made between one preventive maintenance per year and none.

Effects of varying preventive maintenance policy

The Forest Maintenance Simulation Model was run for a ten-year period on a hypothetical medium sized Forest. The pertinent information on the radio equipment inventory by district and distances between districts for the Forest is shown in Tables 22a, 22b, page 105. One technician serviced the entire Forest.

The statistical distributions for time between failures and service times (described in the previous sections) were used to simulate failures and maintenance servicings, respectively.

Three different maintenance policies were run:

1) No Preventive Maintenance on any equipment
2) One Preventive Maintenance per year on all equipment
3) Two preventive Maintenance per year on Fixed Stations; one Preventive Maintenance per year on mobiles and portables.

The results are summarized in Table 23, page 106. The significance of the results is:

1) Additional preventive maintenance did not reduce the failure rate. (This result follows directly from the underlying distributions.)
2) The amount of time the technician spent on servicing equipment and traveling to perform servicing is increased as the preventive maintenance frequency is increased (i.e., the Utilization Percentage is increased)
3) The Equipment Availability (i.e., percentage of time that the equipment is on line) decreased as the Preventive Maintenance frequency is increased.

In essence, what these results mean is that the time spent on preventive maintenance is wasted technician time which decreases the amount of time that equipment is available for normal operation.

It should be noted that the Forest Maintenance Simulation Model was run using the exponential time to next failure distributions to simulate failure times. Consequently, the results (which indicate no improvement in failure rate attributable to preventive maintenance) are due to the results derived from the statistical analysis (described in the preceding sections).

All failure and service times were generated by using random numbers which fit given probability distributions (i.e., Monte Carlo techniques). This accounts for small differences in total travel times and maintenance service times between policies examined.

Figure 3. Average number of breakdowns per year as a function of equipment age

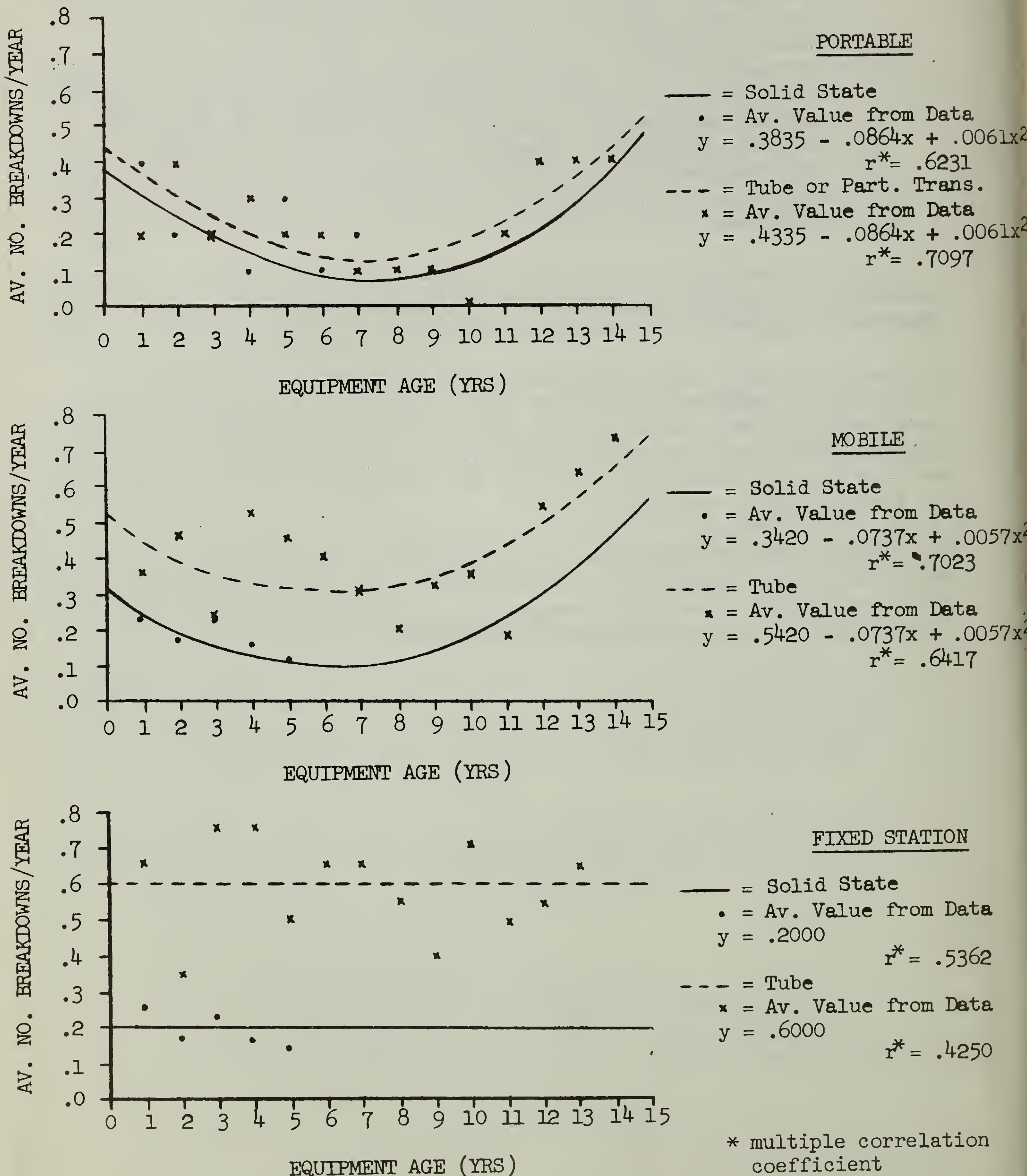


Table 20. Acceptable breakdown rates for radio communications equipment.

Acceptable Average Number of Breakdowns per Year

Region	Fixed Station	Mobile	Portable
1	4	4	4
3	2	4	4
4	0	4	8
5	2	2	4
6	2	8	8
8	4	4	4
9	2	2	2
Regional Average	2.29	4.00	4.86

Note 1: The information shown is a summary of opinions given by 8 Regional Electronics Engineers in response to the regional questionnaire.

Note 2: Original questionnaire answers were given in terms of acceptable breakdown rates per season. Conversion to yearly rates was accomplished by using the "worst case" (i.e., lowest) seasonal rate and multiplying by four. This implies a uniform failure distribution over the year.

Figure 4. Average service time per breakdown as a function of equipment age

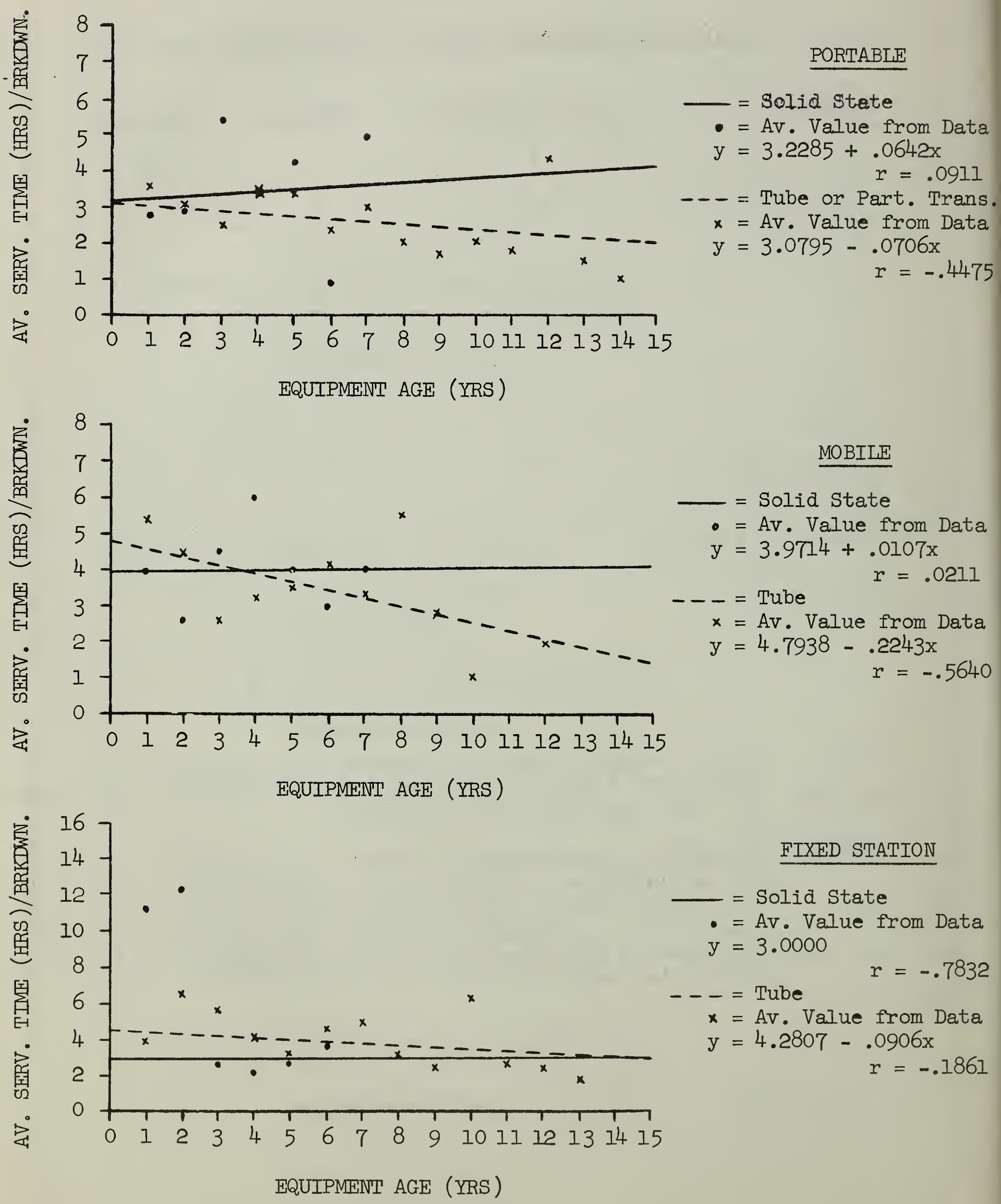


Figure 5. Average parts cost per breakdown as a function of equipment age

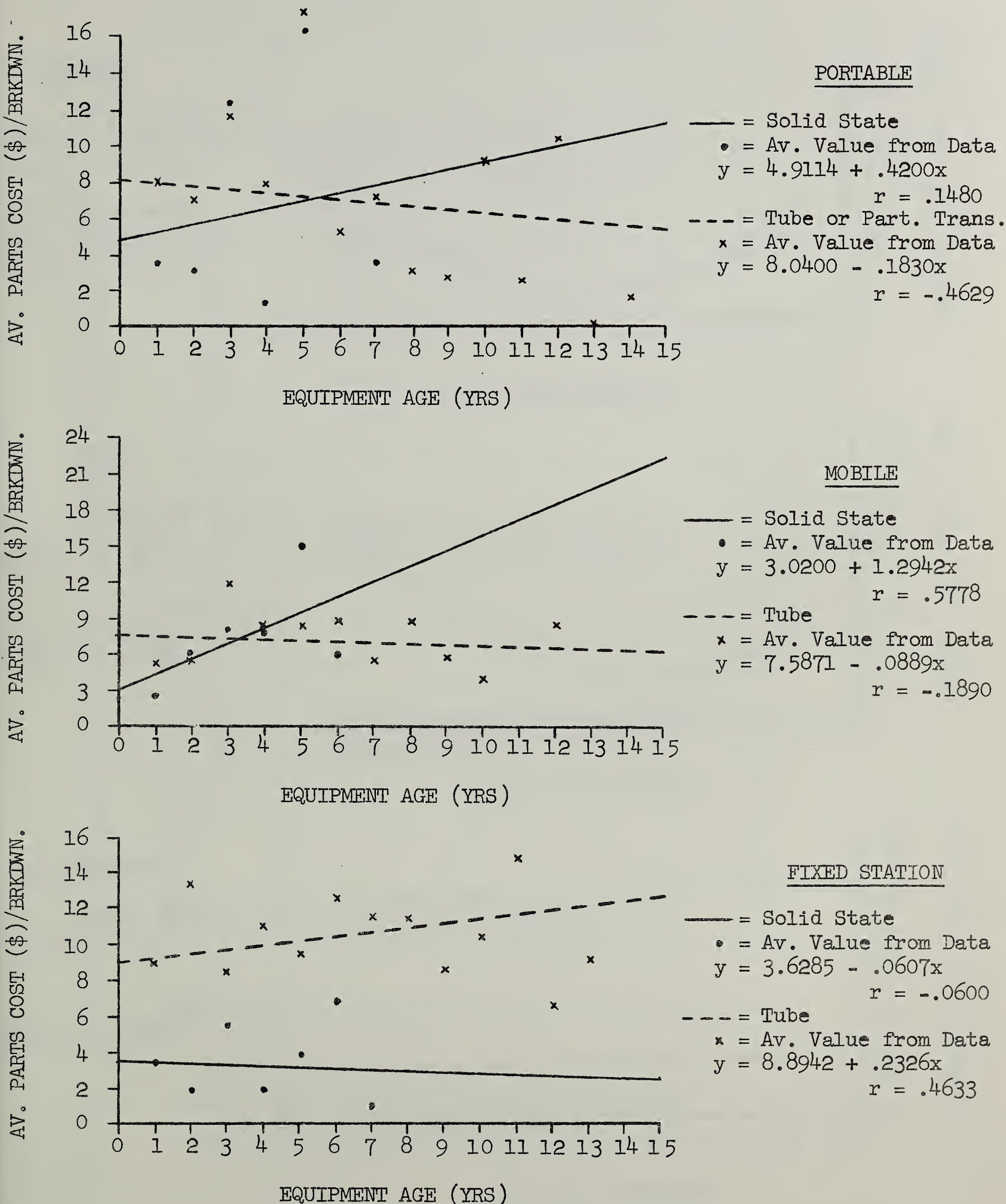


Figure 6. Variable maintenance cost per year as a function of equipment age

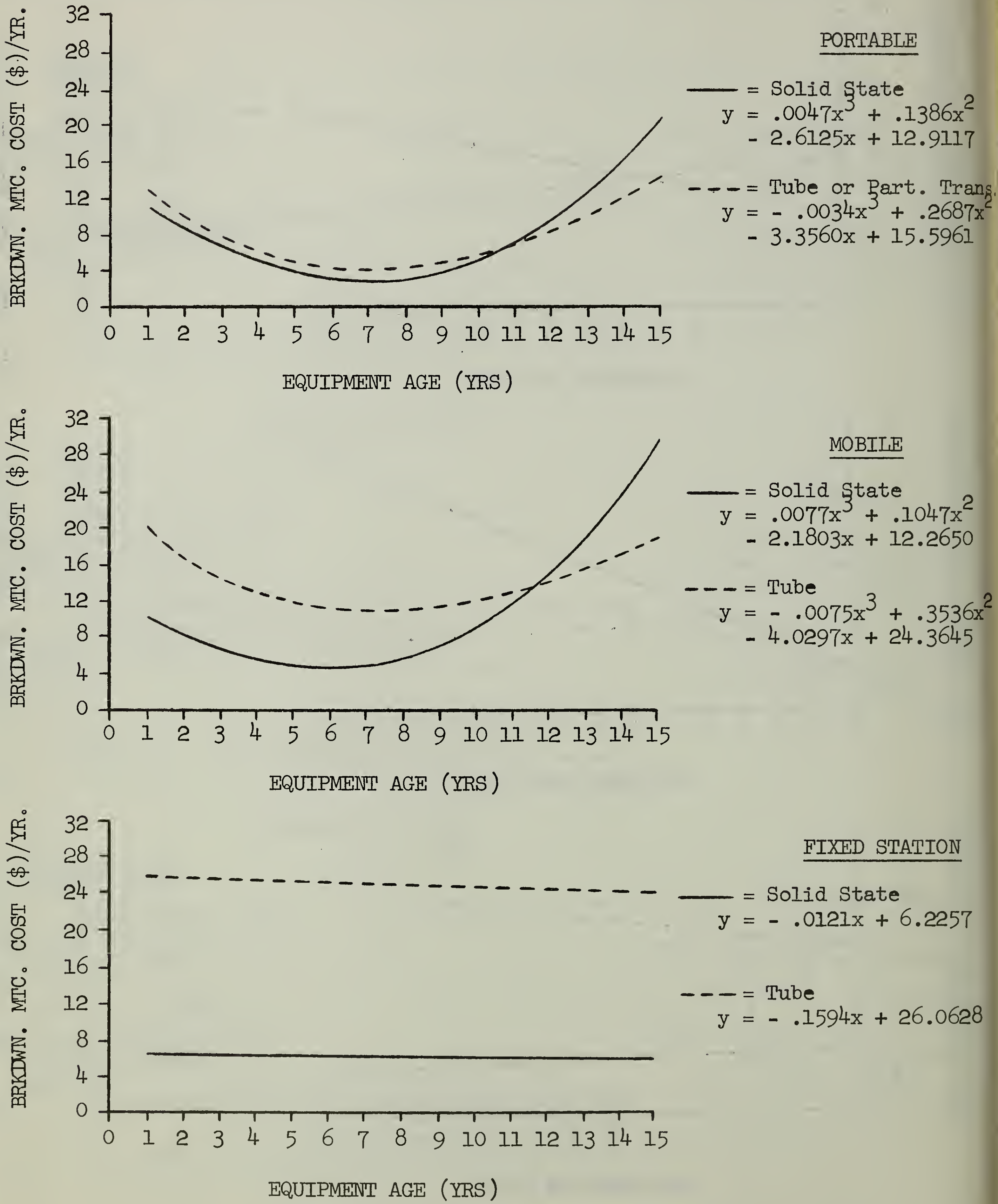


Table 21. Total yearly Forest Service costs of various replacement policies including purchase, maintenance and obsolescence costs and adjustment for salvage values.

Replacement Age	Annual Composite Unit Cost			Salvage Value	Unit Total	F.S. Yearly Total	Yearly Cost Difference (From Optimum)
	Purchase	Maintenance	Obsolescence				
Years	$	$	$	$	$	$ (22,000 units)	$
5	136.71	13.40	21.00	14.25	156.86	3,450,920	978,340
6	113.93	12.74	24.50	10.56	140.61	3,093,420	620,840
7	97.65	12.26	28.00	9.03	128.88	2,835,360	362,780
8	85.45	11.91	31.50	7.16	121.70	2,677,400	204,820
9	75.95	11.68	35.00	2.10	120.53	2,651,660	179,080
10	68.36	11.57	38.50	1.61	116.82	2,570,040	97,460
11	62.14	11.51	42.00	1.26	114.39	2,516,580	44,000
12	56.96	11.54	45.50	.99	113.01	2,486,220	13,640
13	52.58	11.62	49.00	.81	112.39	2,472,580	—
14	48.83	11.82	52.50	.62	112.53	2,475,660	3,080
15	45.57	12.13	56.00	.49	113.21	2,490,620	18,040
16	42.72	12.68	59.50	.40	114.51	2,519,220	46,640
17	40.21	13.39	63.00	.32	116.28	2,558,160	85,580
18	37.96	14.28	66.50	.25	118.49	2,606,780	134,200
19	35.97	15.36	70.00	.15	121.18	2,665,960	193,380

Table 21. Cont. Total yearly Forest Service costs of various replacement policies including purchase, maintenance and obsolescence costs and adjustment for salvage values.

Replacement Age	Annual Composite Unit Costs			Salvage Value	Unit Total	F.S. Yearly Total	Yearly Cost Differences (From Optimum)
	Purchase	Maintenance	Obsolescence				
Years	$	$	$	$	$	$ (22,000 units)	$
5	136.71	13.40	31.50	14.25	167.36	3,681,920	703,340
6	113.93	12.74	36.75	10.56	152.86	3,362,920	384,340
7	97.65	12.26	42.00	9.03	142.88	3,143,360	164,780
8	85.45	11.91	47.25	7.16	137.45	3,023,900	45,320
9	75.95	11.68	52.50	2.10	138.03	3,036,660	58,080
10	68.36	11.57	57.75	1.61	136.07	2,993,540	14,960
11	62.14	11.51	63.00	1.26	135.39	2,978,580	--
12	56.96	11.54	68.25	.99	135.76	2,986,720	8,140
13	52.58	11.62	73.50	.81	136.89	3,011,580	33,000
14	48.83	11.82	78.75	.62	138.78	3,053,160	74,580
15	45.57	12.13	84.00	.49	141.21	3,106,620	128,040
16	42.72	12.68	89.25	.40	144.25	3,173,500	194,920
17	40.21	13.39	94.50	.32	147.78	3,251,160	272,580
18	37.96	14.28	99.75	.25	151.74	3,338,280	359,700
19	35.97	15.36	105.00	.15	156.18	3,435,960	457,380

Table 21. Cont. Total yearly Forest Service costs of various replacement policies including purchase, maintenance and obsolescence costs and adjustment for salvage values.

Replacement Age	Annual Composite Unit Cost			Salvage Value	Unit Total	F.S. Yearly Total	Yearly Cost Difference (From Optimum)
	Purchase	Maintenance	Obsolescence				
Years	$	$	$	$	$	$ (22,000 units)	$
5	136.71	13.40	42.00	14.25	177.86	3,912,920	542,520
6	113.93	12.74	49.00	10.56	165.11	3,632,420	262,020
7	97.65	12.26	56.00	9.03	156.88	3,451,360	80,960
8	85.45	11.91	63.00	7.16	153.20	3,370,400	—
9	75.95	11.68	70.00	2.10	155.53	3,421,660	51,260
10	68.36	11.57	77.00	1.61	155.32	3,417,040	46,640
11	62.14	11.51	84.00	1.26	156.39	3,440,580	70,180
12	56.96	11.54	91.00	.99	158.51	3,487,220	116,820
13	52.58	11.62	98.00	.81	161.39	3,550,580	180,180
14	48.83	11.82	105.00	.62	165.03	3,630,660	260,260
15	45.57	12.13	112.00	.49	169.21	3,722,620	352,220
16	42.72	12.68	119.00	.40	174.01	3,828,220	457,820
17	40.21	13.39	126.00	.32	179.28	3,944,160	573,760
18	37.96	14.28	133.00	.25	184.99	4,069,780	699,380
19	35.97	15.36	140.00	.15	191.18	4,205,960	835,560

Figure 9. Salvage values as a function of age

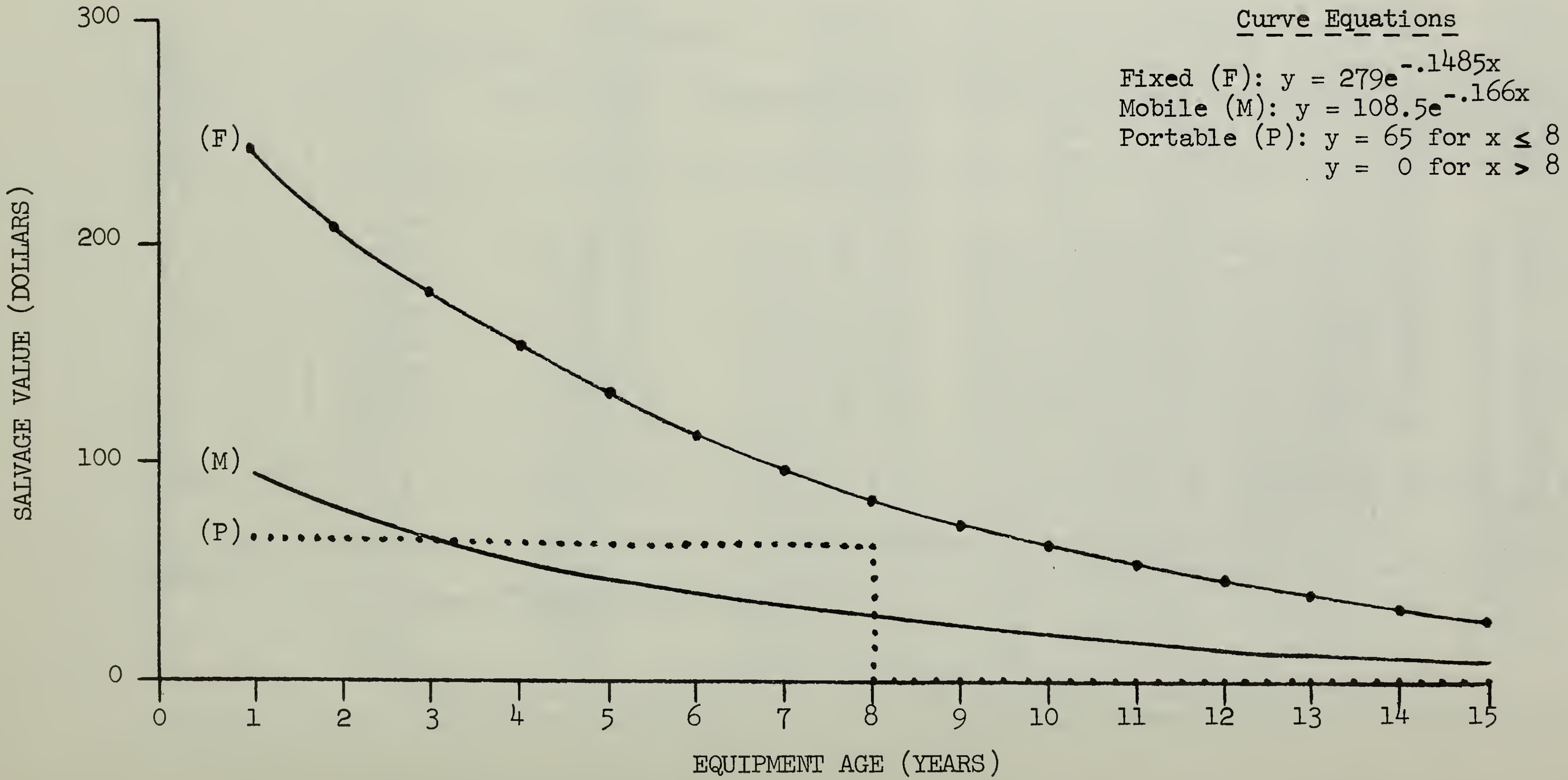
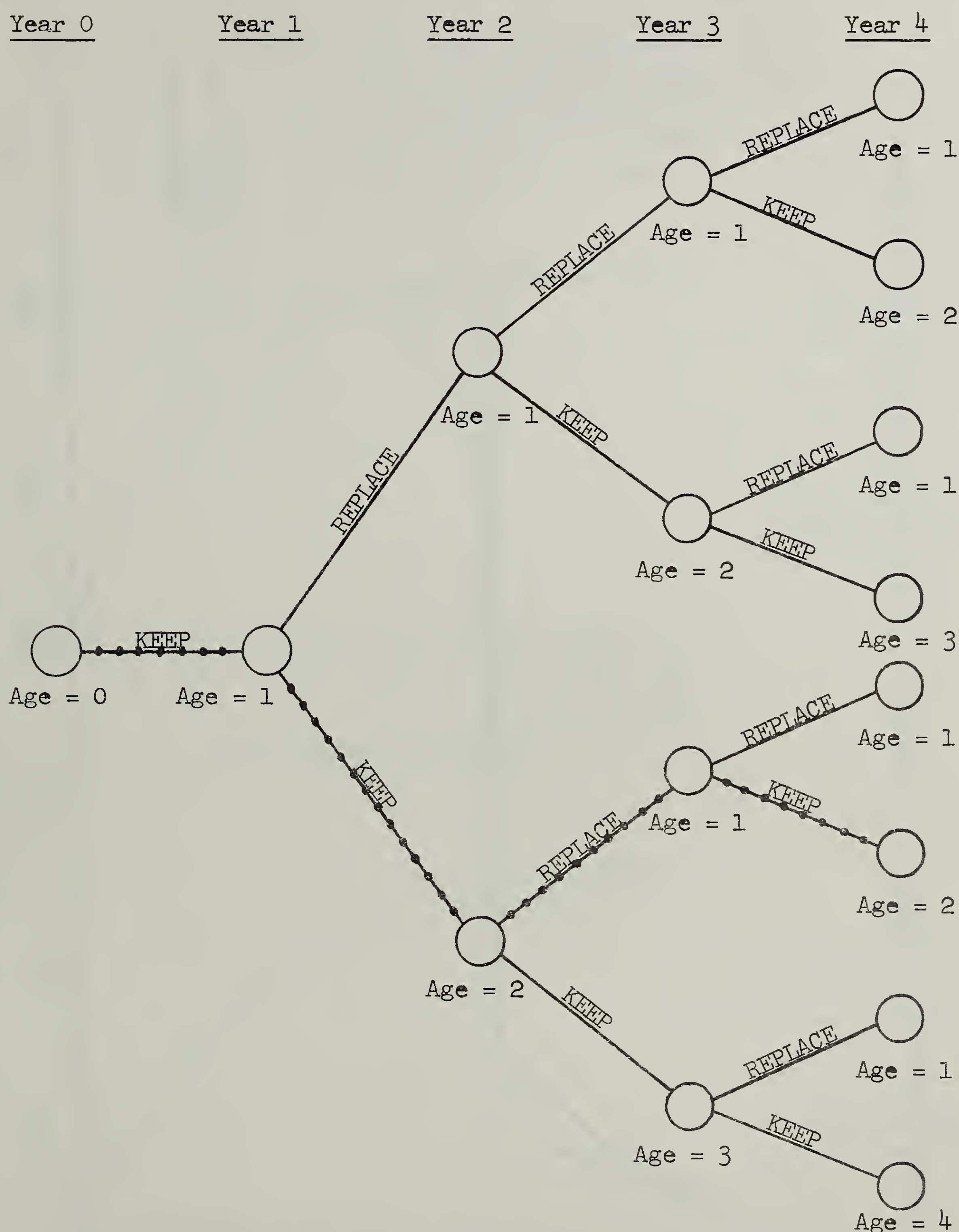


Figure 10. Replacement policy network diagram



• • • • • • • = One Replacement Policy (KEEP, KEEP, REPLACE, KEEP) chosen at random.
TOTAL COST = Annual KEEP Decision Cost (Age = 0) + Annual KEEP Decision Cost (Age = 1) + Annual REPLACE Decision Cost (Age = 2) + Annual KEEP Decision Cost (Age = 1) + Cost Of Money.

Figure 11. Optimal replacement policy as a function of ten year obsolescence cost savings

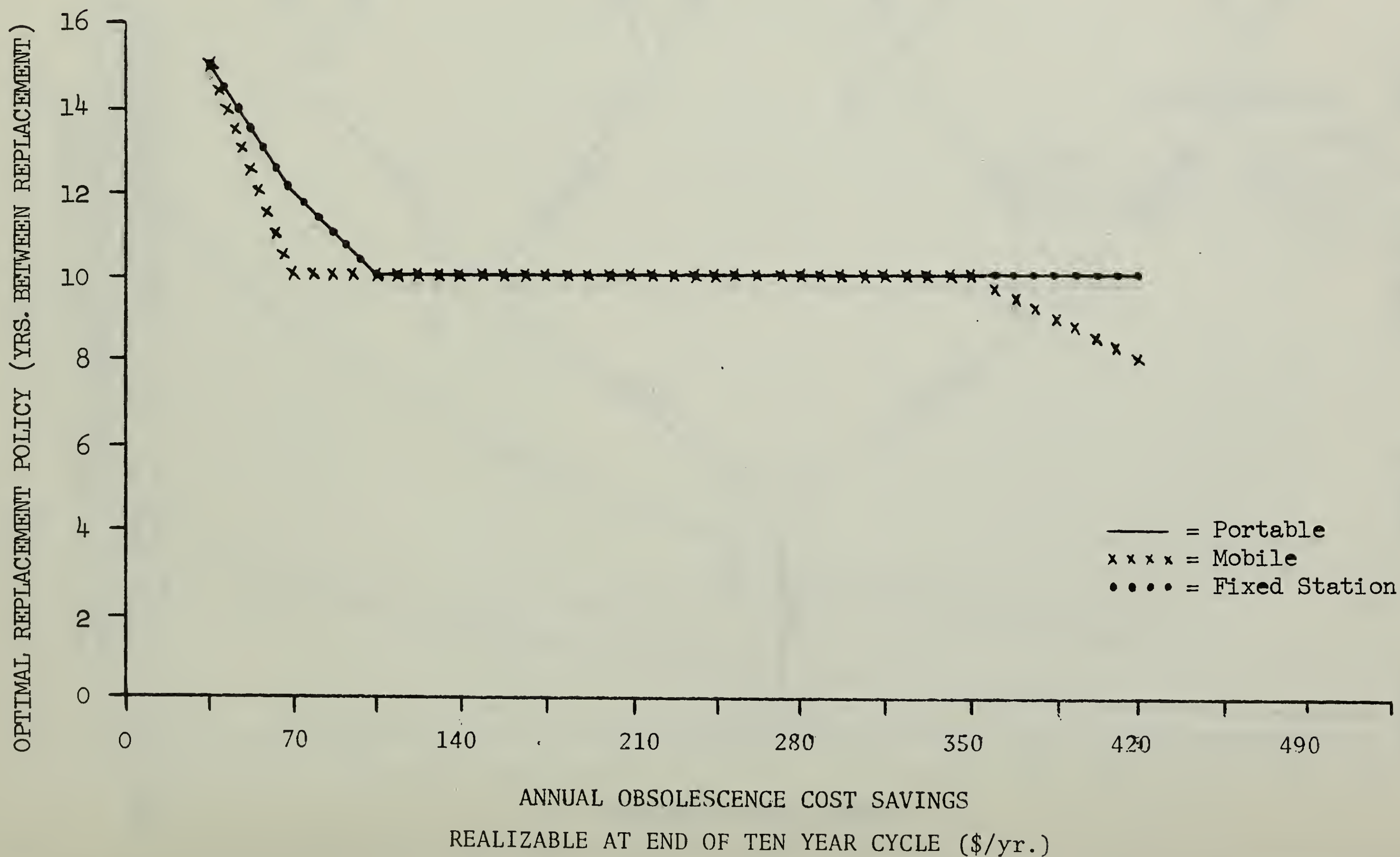
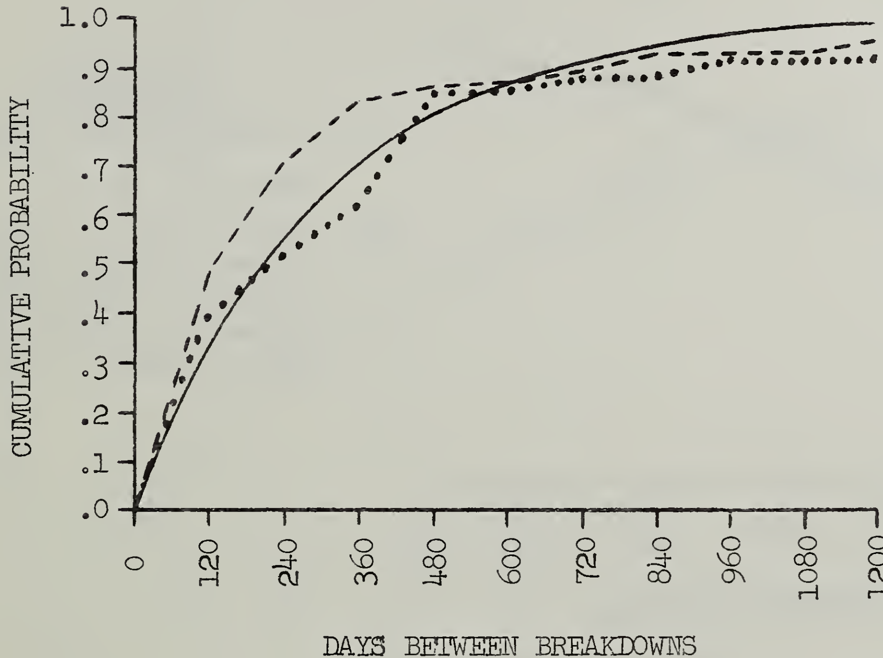


Figure 12. Cumulative probability distribution of time between breakdowns for fixed stations

General legend: χ^2_{1C} = Calculated Chi-Squared Value for 1 Preventive Mtc./Yr.
χ^2_{2C} = Calculated Chi-Squared Value for 2 Preventive Mtc./Yr.
The Significant Chi-Squared Value = $\chi^2_{10,.95}$ = 18.30 for α = .05

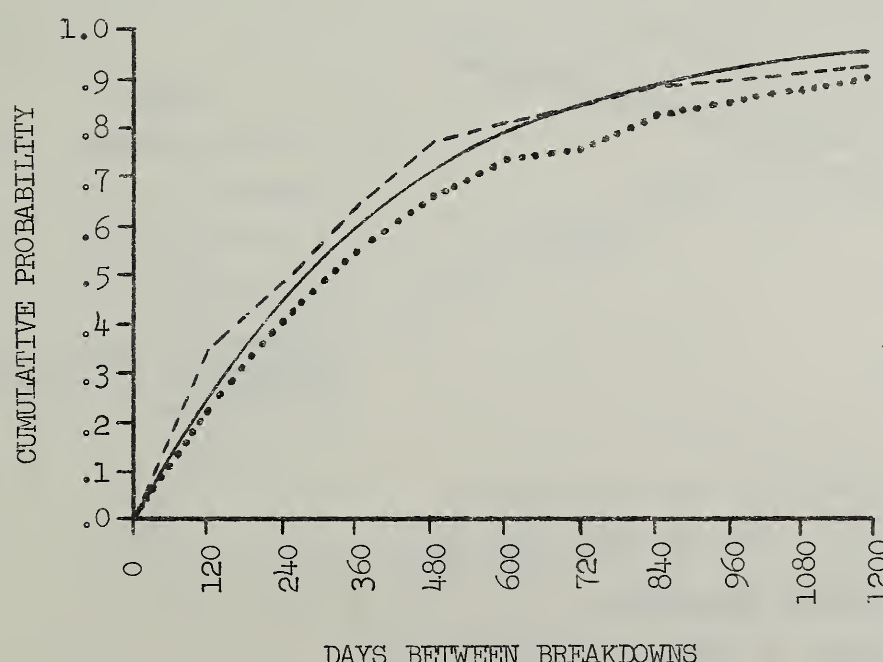


SUBSTANTIALLY TRANSISTORIZED

- - - = 1 Preventive Mtc./Yr.*
where: χ^2_{1C} = 13.94

• • • • = 2 Preventive Mtc./Yr.*
where: χ^2_{2C} = 17.89

——— = Theoretical Exponential Probability Distribution with the mean = 300



TUBE

- - - = 1 Preventive Mtc./Yr.*
where: χ^2_{1C} = 17.54

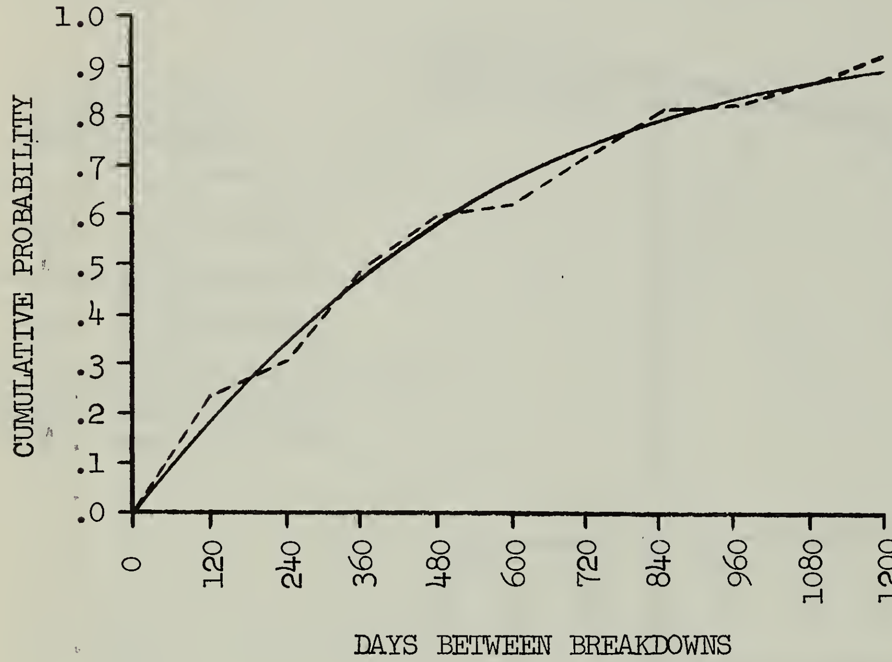
• • • • = 2 Preventive Mtc./Yr.*
where: χ^2_{2C} = 17.03

——— = Theoretical Exponential Probability Distribution with the mean = 380

*Note: Distribution based on "actual" data.

Figure 13. Cumulative probability distribution of time between breakdowns for mobiles

General Legend: χ^2_{1C} = Calculated Chi-Squared Value for 1 Preventive Mtc./Yr.
χ^2_{2C} = Calculated Chi-Squared Value for 2 Preventive Mtc./Yr.
The Significant Chi-Squared Value = $\chi^2_{10,.95} = 18.30$ for $\alpha = .05$

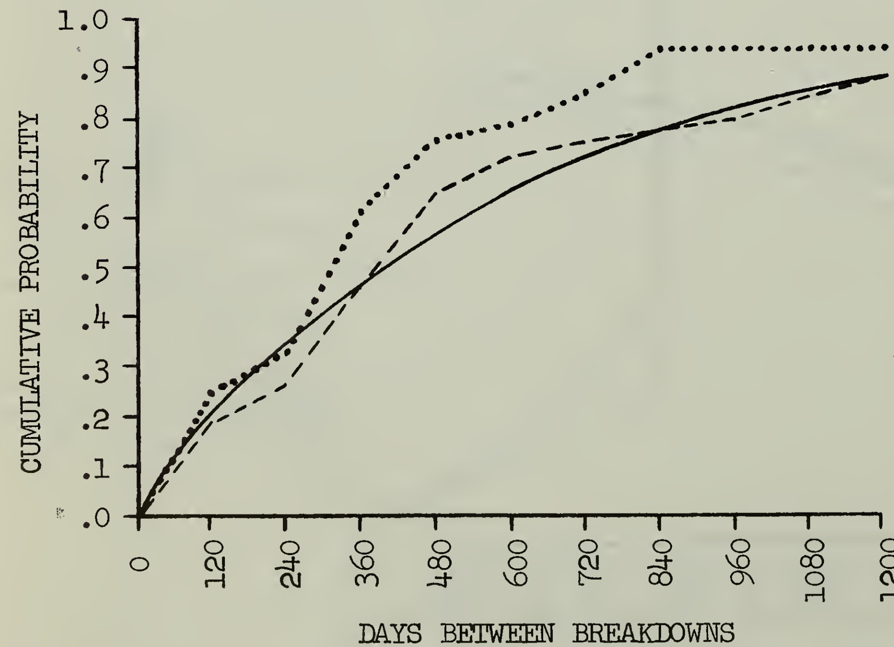


SUBSTANTIALLY TRANSISTORIZED

---= 1 Preventive Mtc./Yr.*
where: $\chi^2_{1C} = 6.93$

Note: Insufficient Data for 2 Preventive Mtc./Yr.

——= Theoretical Exponential Probability Distribution with the mean = 550



TUBE

---= 1 Preventive Mtc./Yr.*
where: $\chi^2_{1C} = 17.65$

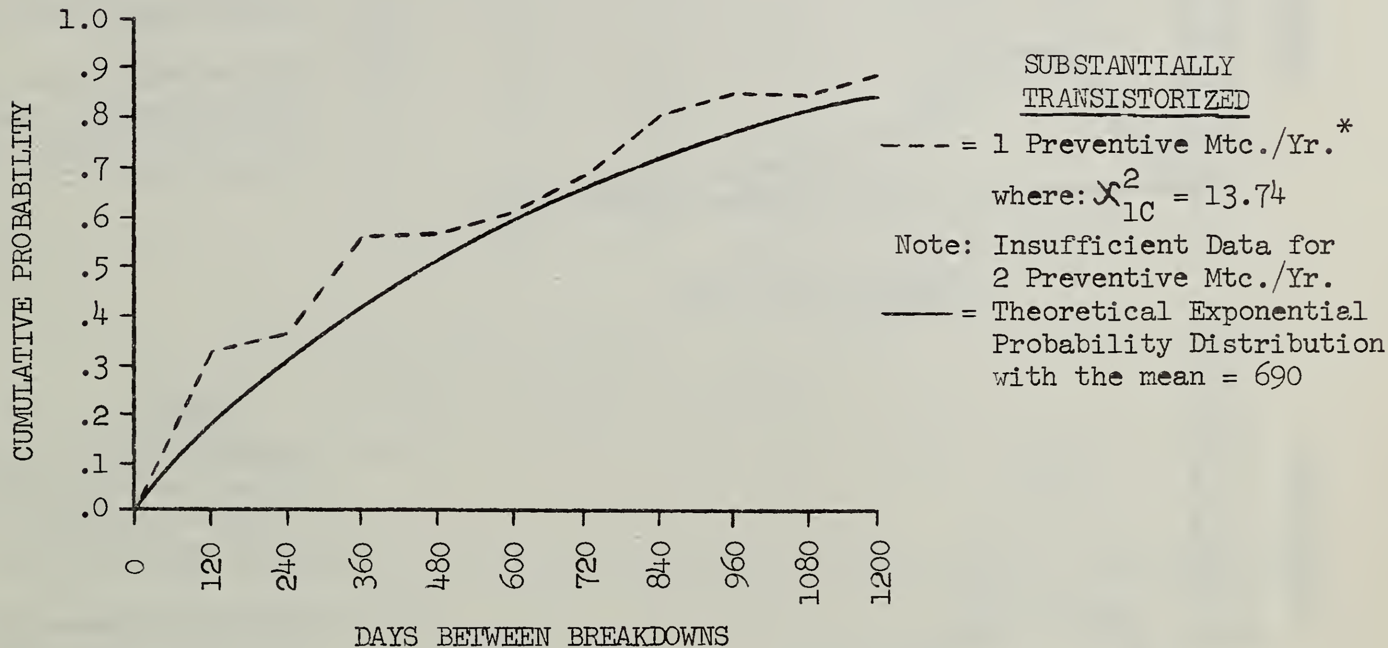
....= 2 Preventive Mtc./Yr.*
where: $\chi^2_{2C} = 12.59$

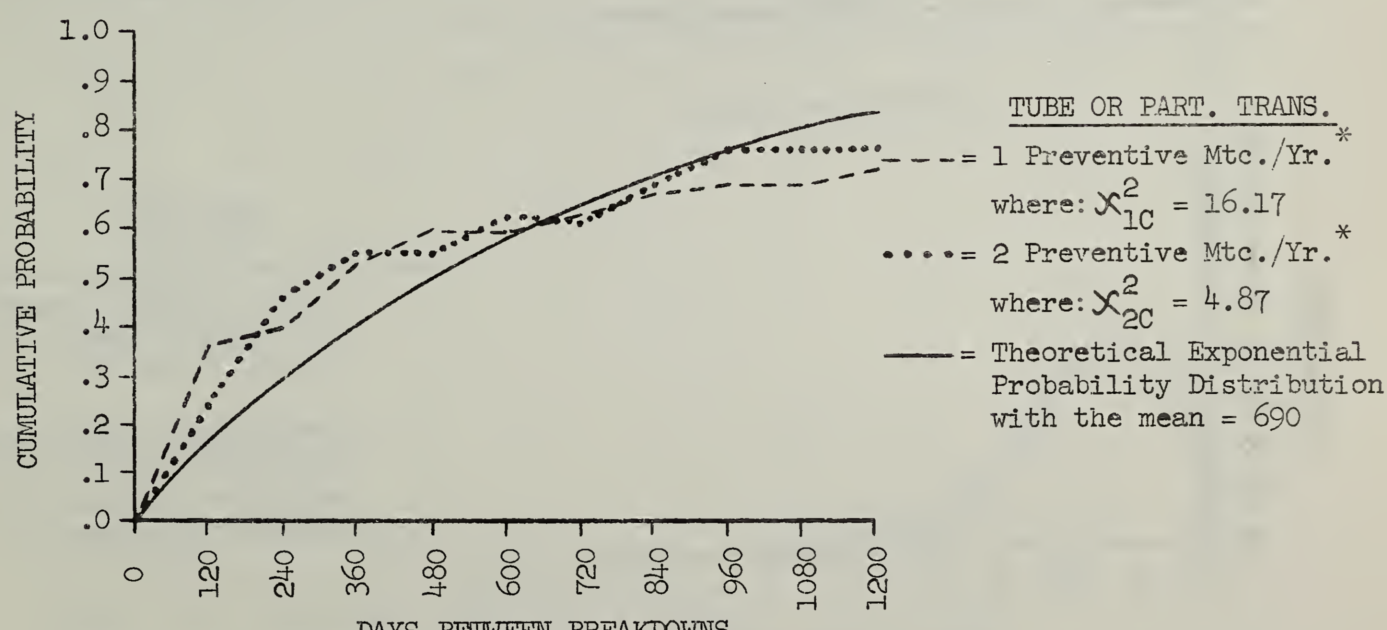
——= Theoretical Exponential Probability Distribution with the mean = 550

*Note: Distribution based on "actual" data.

Figure 14. Cumulative probability distribution of time between breakdowns for portables

General Legend: χ^2_{1C} = Calculated Chi-Squared Value for 1 Preventive Mtc./Yr.
χ^2_{2C} = Calculated Chi-Squared Value for 2 Preventive Mtc./Yr.
The Significant Chi-Squared Value =
$\chi^2_{10,.95} = 18.30$ for $\alpha = .05$





*Note: Distribution based on "actual" data.

Figure 15. Breakdown and preventive Mtc. service time probability distributions (Note: B.M. = Breakdown Mtc. and P.M. = Preventive Mtc.)

Gamma Probability Distribution

$$f(x;\alpha;\beta) = \frac{1}{\alpha!\,\beta^{\alpha+1}} \cdot x^{\alpha} e^{-x/\beta}$$

where x = service time.

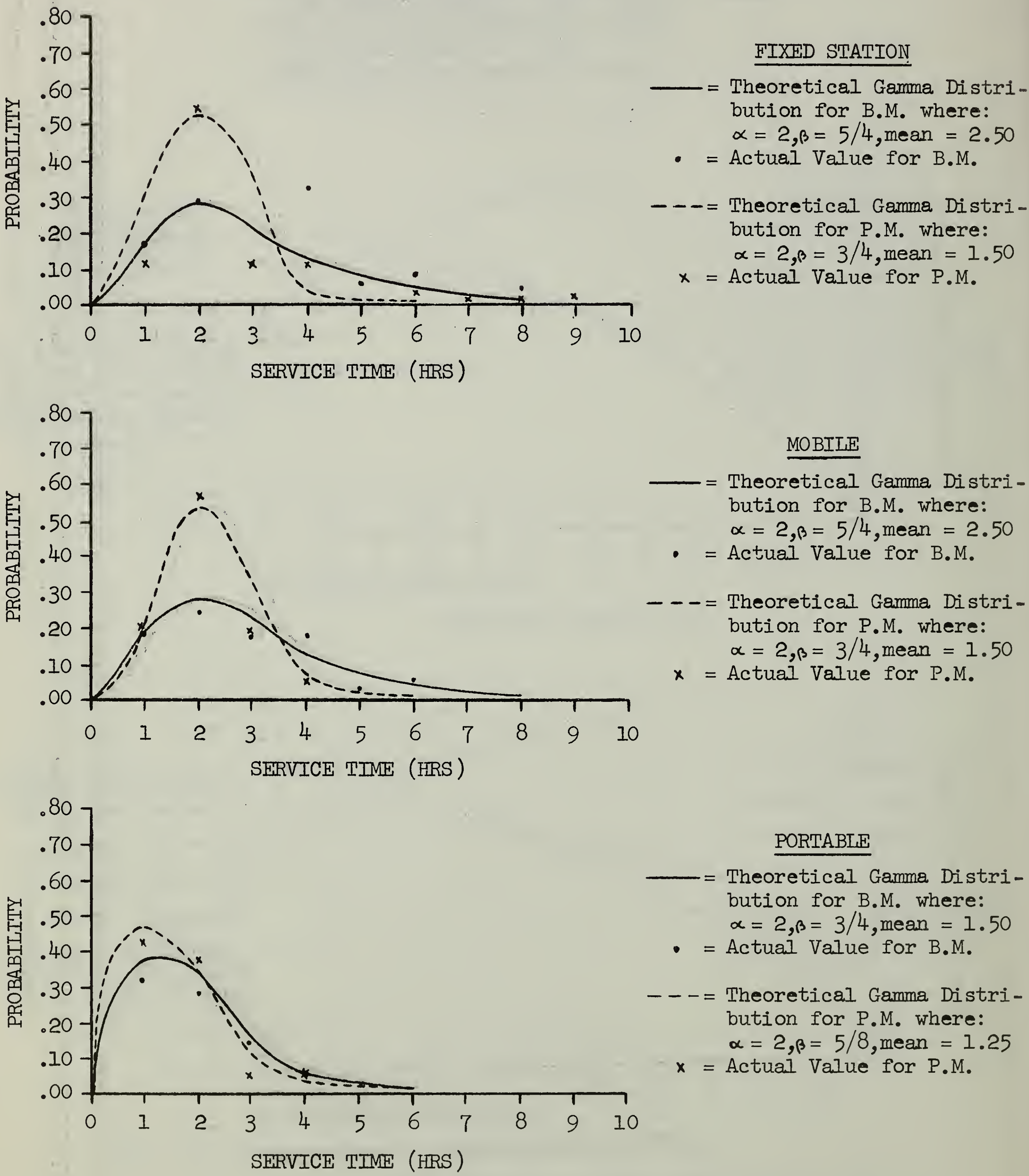


Table 22a. Data on sample forest used during forest maintenance simulation model runs. Distance between districts (miles).

From \ To	S.O.	District 1	District 2	District 3	District 4	District 5	District 6
S.O.	0	60	60	30	60	60	30
District 1	60	0	30	30	120	120	60
District 2	60	30	0	30	120	120	60
District 3	30	30	30	0	90	90	60
District 4	60	120	120	90	0	0	30
District 5	60	120	120	90	0	0	30
District 6	30	60	60	60	30	30	0

Note: 1) The forest has six districts and a supervisor's office.
2) Travel speed was assumed to be 30 m.p.h.
3) S.O. indicates Supervisor's Office

Table 22b Equipment inventory by district and supervisor's headquarters.

Equipment	S.O.	District 1	District 2	District 3	District 4	District 5	District 6
Fixed Sta. (tube)	3	4	1	2	3	3	2
Mobile (tube)	8	7	7	7	7	7	7
Portable (tube or part. trans)	6	7	6	6	6	6	6
Portable (solid state)	2	0	1	0	1	0	0
TOTAL(115)	19	18	15	15	17	16	15

Note: S.O. indicates Supervisor's Office

Table 23. Comparison of different maintenance policies on forest maintenance simulation model.

Policy Evaluation Criteria	Policy 1*	Policy 2**	Policy 3***
Average travel time/yr. (hrs.)	183 hrs.	196 hrs.	192 hrs.
Average P.M. service time/yr (hrs.)	0 hrs.	156 hrs.	319 hrs.
Average B.M. service time/yr (hrs.)	106 hrs.	114 hrs.	113 hrs.
Technician Utilization (Percent of time technician is busy servicing equipment or travelling)	15 %	24 %	32 %
Fixed station availibility (Percent of time fixed stations are "on-line")	99.4 %	98.7 %	98.2 %
Mobile availibility (Percent of time mobiles are "on-line")	99.7 %	99.4 %	99.1 %
Portable availibility (Percent of time portables are "on-line")	99.9 %	99.6 %	99.7 %

* Policy 1: No P.M./year on any equipment

** Policy 2: 1 P.M./year on all equipment

***Policy 3: 1 P.M./year for mobiles and portables
2 P.M./year for fixed stations

At the present time neither the Federal Communications Commission nor the Interdepartmental Radio Advisory Committee require any specific periodic equipment checks. They require only that transmitting equipment remain within certain frequency, modulation, and power limits. These limits are generally broad enough for present day equipment to be considered in a breakdown condition if these limits were exceeded.

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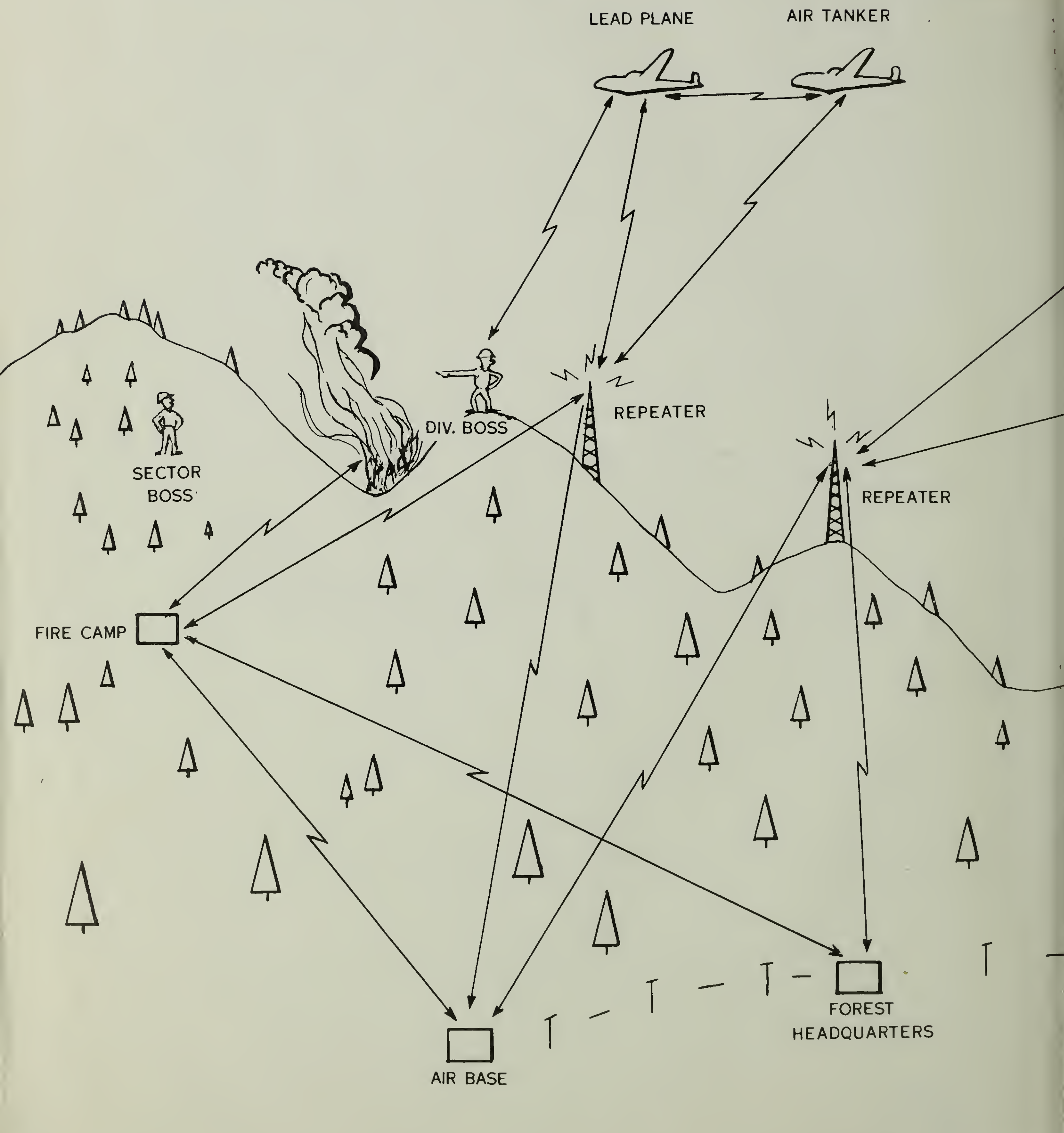
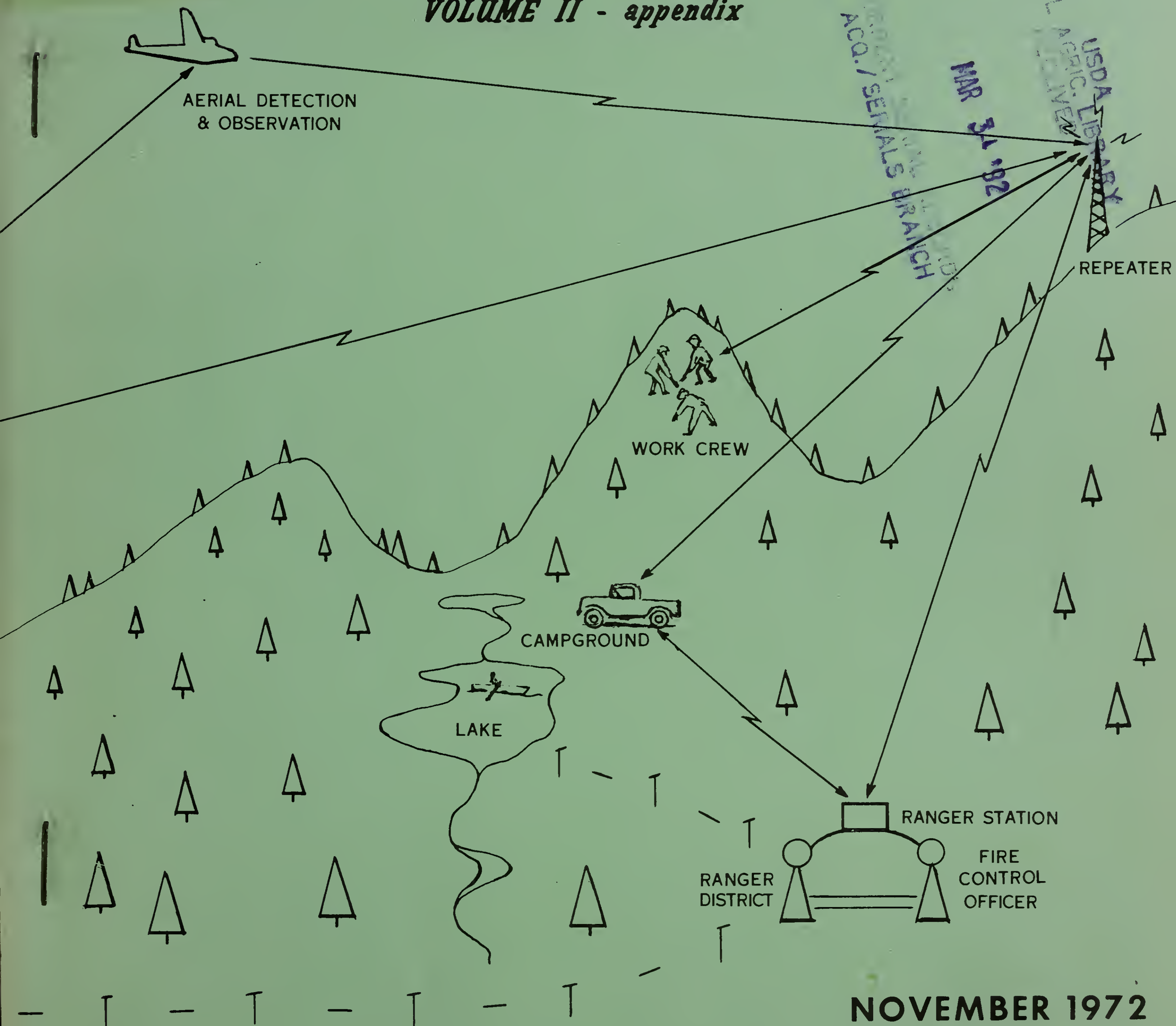
GPO 940-996


LEAD PLANE
AIR TANKER
REPEATER
DIV. BOSS
SECTOR BOSS
REPEATER
FIRE CAMP
FOREST HEADQUARTERS
AIR BASE

Requirements, Replacement & Maintenance

A STUDY OF FOREST SERVICE TELECOMMUNICATIONS

VOLUME II - appendix



NOVEMBER 1972

FOREST SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

SERVICE-WIDE TELECOMMUNICATIONS STUDY

Volume II

Requirements Evaluation

Replacement and Maintenance Policies

APPENDIX

November 1972

TABLE OF CONTENTS

EXHIBITS (cont.)

Table A1 Capital Recovery Factors at: 6%, 8%, 10% and 12% Interest

Interest	Amortization Period in Years				
	5 Years	7 Years	10 Years	12 Years	15 Years
6%	0.2374	0.1791	0.1354	0.1193	0.1030
8%	0.2505	0.1921	0.1491	0.1327	0.1168
10%	0.2638	0.2054	0.1627	0.1468	0.1315
12%	0.2774	0.2191	0.1770	0.1614	0.1468

Table A2.

AMORTIZED CAPITAL COSTS PER YEAR

(Amortization rate at 7% per year)

Capital Cost Per Item	Expected Equipment Life Span in Years: 7 yrs.* (.1856)	10 yrs.* (.1424)	12 yrs.* (.1259)	15 yrs.* (.1098)
$100	$18.56	$14.24	$12.59	$10.98
200	37.12	28.48	25.18	21.96
300	55.68	42.72	37.77	32.94
400	74.24	56.96	50.36	43.92
500	92.80	71.20	62.95	54.90
600	111.36	85.44	75.54	65.88
700	129.92	99.68	88.13	76.86
800	148.48	113.92	100.72	87.84
900	167.04	128.16	113.31	98.92
1000	185.60	142.40	125.90	109.80
1100	204.16	156.64	138.49	120.78
1200	222.72	170.88	151.08	131.76
1300	241.28	185.12	163.67	142.74
1400	259.84	199.36	176.26	153.72
1500	278.40	213.60	188.85	164.70
1600	296.96	227.84	201.44	175.68
1700	315.52	242.08	214.03	186.66
1800	334.08	256.32	226.62	197.64
1900	352.64	270.56	239.21	208.62
2000	371.20	284.80	251.80	219.60
2100	389.76	299.04	264.39	230.58
2200	408.32	313.28	276.98	241.56
2300	426.88	327.52	289.57	252.54
2400	445.44	341.76	302.16	263.52
2500	464.00	356.00	314.75	274.50
2600	482.56	370.24	327.34	285.48
2700	501.12	384.48	339.93	296.46
2800	519.68	398.72	352.52	307.44
2900	538.24	412.96	365.11	318.42
3000	556.80	427.20	377.70	329.40
3100	575.36	441.44	390.29	340.38
3200	593.92	455.68	402.88	351.36
3300	612.48	469.92	415.47	362.34
3400	631.04	484.16	428.06	373.32
3500	649.60	498.40	440.65	384.30
3600	668.16	512.64	453.24	395.28
3700	686.72	526.88	465.88	406.26
3800	705.28	541.12	478.42	417.24
3900	723.84	555.36	491.01	428.22
4000	742.40	569.60	503.60	439.20

*Capital Recovery Factor (CRF) at 7% interest.

Table A3 Average Annual Cost Breakdown (Dollars) Of Maintenance and Repair of New Equipment (0-7 yrs)

Region	Fixed Base Stations			Mobiles			Portables (heavy)			Portables (light)		
	Labor	Parts	Total	Labor	Parts	Total	Labor	Parts	Total	Labor	Parts	Total
1.	No data*											
2.	312	18	330	100	15	115	100	15	115	81	15	96
3.	170	16	186	115	16	131	90	10	100	90	10	100
4.	214	10	224	190	10	200	157	5	162	120	4	124
5.	229	20	244	161	19	198	167	12	192	91	11	112
6.	247	50	297	55	20	75	31	5	23	31	5	36
8.	Unusable data											
9.	108	12	120	89	11	100	50	10	60	50	10	60
Overall Weighted Average	220	20	239	123	16	144	117	8	125	63	8	74

*Region-wide average cost is 110% of W. O. maintenance base.

Table A3(cont) Average Annual Cost Breakdown (Dollars) Of Maintenance and Repair of New Equipment (0-7 yrs)

Region	Repeater (battery)			Repeater (a.c.)			Radio Links		
	Labor	Parts	Total	Labor	Parts	Total	Labor	Parts	Total
1.	No data*								
2.	100	15	115	312	18	330	312	18	330
3.	100	10	110	170	16	186	176	16	186
4.	221	15	236	209	15	224	209	15	224
5.	229	20	249	229	20	274	229	20	249
6.	247	50	297	247	50	297	247	50	297
8.	No data								
9.	164	16	180	203	22	225	215	25	240
Overall Weighted Average	220	29	249	241	21	267	237	26	262

---

*Region-wide average cost is 110% of W. O. maintenance base.

Table A4 Average Annual Cost Breakdown (Dollars) Of Maintenance and Repair of Old Equipment (7^+ yrs)

Region	Fixed Base Stations			Mobiles			Portables (heavy)			Portables (light)		
	Labor	Parts	Total	Labor	Parts	Total	Labor	Parts	Total	Labor	Parts	Total
1.	No data											
2.	No data											
3.	No data											
4.	254	50	304	221	40	261	162	30	192	128	25	153
5.	254	20	274	179	19	198	180	12	192	101	11	112
6.	247	65	312	55	23	78	31	15	46	31	15	46
8.	Unusable data											
9.	117	18	135	99	16	115	58	12	70	58	12	70
Overall Weighted Average	227	36	263	142	24	166	129	22	151	63	14	77

Table A4 (cont.) Average Annual Cost Breakdown (Dollars) Of Maintenance and Repair of Old Equipment (7^{+} yrs)

Region	Repeater (battery)			Repeater (a.c.)			Radio Links		
	Labor	Parts	Total	Labor	Parts	Total	Labor	Parts	Total
1.	No data								
2.	No data								
3.	No data								
4.	229	30	259	212	74	286	212	50	262
5.	254	20	274	254	20	274	254	20	274
6.	247	65	312	247	65	312	247	65	312
8.	No data								
9.	184	16	200	247	28	275	275	35	310
Overall Weighted Average	240	43	283	242	39	281	243	44	286

MOBILE RADIOS

Motorola contract number	Name of items and number	Rental w/mtc per mo.	Rental w/o mtc per mo.	Install	Remove	Agreed value
719	Motrac Mobile U53MHT	$22.43	$17.43	$27.50	$65.00	$807.00
	F. S. Ashley					484.00
721 or 722	Motrac Mobile U43MHT	22.80	16.80	27.50	25.00	778.00
	Universal or trunk					
	SL cache, R-4					366.00
719	Motrac Mobile U63MHT	23.43	17.43	27.50	36.50	807.00
	Targhee					466.00
	Av/mo	$22.89	$17.22	$27.50	$42.17	
	Av/yr	274.68	206.64			
	Av/yr (with 8% incremental)	296.65	223.17	29.70	45.54	
	Install remove prorate 10 yrs			2.97	4.55	
	Total cost/yr	304.17	230.69			
	Maintenance travel	25.00				
	Unavailability (4 x 5.00)	20.00				
	Total	$349.17	$230.69			

Table A5 (cont)

BASE STATION (TABLE TOP)

Motorola contract number	Name of Items and numbers	Rental w/mtc per mo.	Rental w/o mtc per mo.	Install	Remove	Agreed value
775	L43GGB 25W	$ 19.06	$ 11.88	$ 15.00	$ 11.00	$495.00
	Ashley NF					
	Cost/yr	228.72	142.56			
	Cost/yr (incl. 8% incr)	247.02	153.96	16.20	11.88	
	Install-remove Prorate over 10 yrs			1.62	1.19	
	Total Cost	249.83	156.77			
	Maintenance Travel	25.00				
	Unavailability Cost (4x$9)	36.00				
Total Rental Cost/yr		$310.83	$156.77			

Table A5 (cont)

BASE STATION (LARGE)

Motorola contract number	Name of items and numbers	Rental w/mtc per mo.	Rental w/o mtc per mo.	Install	Remove	Agreed value
778	C53 GKB 60 W Code NF	$ 28.28	$ 17.28	$ 25.00	$160.00	$720.00
	Av. cost/yr	339.36	207.36			
	Av. cost/yr (8% incr) 1968-71	366.51	223.95	27.00	17.28	
	Install-remove Prorate over 10 yrs			2.70	1.73	
	Total cost/yr	370.94	228.38			
	Maintenance Travel	25.00				
	Unavailability (4x$11.00)	44.00				
	Total Rental cost/yr	$439.94	$228.38			

Table A5 (cont)

PERSONAL PORTABLE AND PACK SETS (LIGHT)

Motorola contract number	Name of item and number	Rental w/ mtc. per mo.	Rental w/o mtc. per mo.	Install	Removal	Agree value
846	p. portable 2W H23 DEN	$18.32	$12.57	$5.00	$7.50	$582.
	F.S.H23 DEN Ashley N.F.					
849	pack set 5W P33 DEN	21.67	17.17	5.00	7.50	795.
	F. S. Ashlèy					
843	pack set 3W P31 DEN	21.67	17.17	5.00	7.50	795.
	F. S. Boise					
841	pack set 14W H21 DCN	18.32	12.57	5.00	7.50	582.
	F. S. Boise (H21AAC)					
	Ave./mo.	$19.96	$14.87	$5.00	$7.50	
	Ave./yr.	239.52	178.44			
	Ave./yr. (8% increment)	258.68	192.72	5.40	8.10	
	Install-Remove prorate 10 yrs			.54	.81	
	Total cost/yr.	260.03	194.07			
	Mtc. Travel	25.00				
	Unavailability (4 x 5.00)	20.00				
	Total	$305.03	194.07			

Table A5 (cont)

PORTABLE - HEAVY

Motorola contract number	Name of items and number	Rental w/mtc per mo.	Rental w/o mtc per mo.	Install	Remove	Agreed value
50	Packset 10W P43 DEN	$ 24.89	$ 20.39	$ 5.00	$ 7.50	$944.00
	N. F. Ashley					
	Cost/yr	298.68	244.68	5.00	7.50	
	Cost/yr (8% incr)	322.57	264.25	5.40	8.10	
	Install-Remove Prorate 10 yrs.			0.54	0.81	
	Total Cost/yr	323.92	265.60			
	Maintenance Travel	25.00				
	Unavailability cost (4x$6)	24.00				
	Total Rental cost/yr	$372.92	$265.60			

Table A5 (cont)

REPEATER AC

Motorola contract number	Name and number of item	Rental w/ mtc. per mo.	Rental w/o mtc. per mo.	Install	Remove	Agreed Value
904	AC Repeater B63 mpy	$56.59	$44.09	$50.00	$65.00	$2041.00
	Cache R4					1120.00
	No battery Repeater but cost F.S. about $1000.00					
	J53 AKY 50W Repeater					1298.00
	Ave/yr.	$ 679.08	$ 529.08			
	Ave/yr. (8% increment)	733.41	571.41	54.00	70.20	
	Install-Remove prorate 10 yrs.	745.83	583.83			
	Mtc. Travel	25.00				
	Unavailability (4 x 12)	48.00				
	Total	$ 818.83	$ 583.83			

Table A6. Equipment Sample

Region 1

Category	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Bitterroot										1					3			1			2			3	
Coeur D'Alene	1	2										2													
Nezperce			2					1							3			2							
Gallatin					1					1					4						2				
Kaniksu								5		2														2	
Deerlodge			1								3										2	3			
St. Joe			3							2	1	2													
Lolo												3													
Kootenai	1	2									2	2						1							
Colville	1	1																1			1			3	
Lewis & Clark	1									3	2	1			2										
Flathead	3																				4				
Helena	2	1								3														3	
Beaverhead	3							1							1			1			3				

Table A6 (cont)

Region 2

Category	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Medicine Bow					4			5		1															
Black Hills					1								3		6										
Arapaho					3			3							2									1	
Nebraska			2																						
San Juan	1		1																						
Bighorn	3	2								2		2													
San Isabel	2	1																							
Grand Mesa-Uncompahgre	2														6										
White River												3			3										
Gunnison																					4			1	

Table A6 (cont)

Region 3

Category	1	2	3	4	5	6	7	8	9	10	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Cibola			3																1				2	
Santa Fe																			10					
Prescott					1						2			3									1	
Gila					4			3													2			
Lincoln					1									2									2	
Apache			1					2				3		1						2			1	
Tonto	3	3																					3	
Kaibab												4												

Table A6 (cont)

Region 4

Category	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Toiyabe	5							3																	
Humbolt			2							2					2									2	
Targhee															2						4				
Ashley		1																3			1			4	
Boise			1					2		1												2			
Payette			1								5		4									1			
Cache		1						2		1															
Caribou													4											4	
Sawtooth		1	3									3												2	
Manti-LaSal			3															1						5	
Uinta		3	2															1						3	
Wasatch				4								2												2	
Teton		3																							

Table A6 (cont)

Region 5

Category	1	2	3	4	5	6	7	8	9	10	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Shasta-Trinity	2	2	1							2		1												
Tahoe					3												3						2	
San Bernardino	2										2			2						2			2	

Table A6 (cont)

Region 6

Category	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Wallowa Whitman								2		2														4	
Fremont																		2				6			
Willamette											5							3						1	
Olympic		3											3											3	
Mt. Baker		3								2			6												
Snoqualmie		3											1											3	
Malheur															3							3		2	
Deschutes															3							6			
Ochoco												2									6				

Table A6 (cont)

Region 9

Category	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Chippewa								3										2						4	
Wayne Hoosier								1			3													5	
Hiawatha					2										3										
Ottawa	2	2																							
Chequamegon					2										1			2						4	
Huron Manistee													1					3						3	
Monongahela															2			3						3	
White Mt.											3							4							
Allegheny								1			1							4							
Superior								1				3			3			1							
Nicolet		2											3		1										
Green Mt.		3										5													

Exhibit B1

TELECOMMUNICATIONS* QUESTIONNAIRE
FOR REGIONAL OFFICE

Your region has been selected to assist the Forest Service Telecommunications Study Team. They need your answers to prepare recommendations for improved communications.

Please relate your answers to calendar year 1970. Give your best estimates only. No detailed analyses are required.

This questionnaire is in two parts. Part A might best be completed by the branch of administrative management, part B by the regional electronics engineer.

Please answer all questions as completely as possible. Attach extra continuation sheets if necessary. If you have any questions, contact the Management Sciences Staff in Berkeley, California.

The self-addressed envelope should be used to mail the questionnaire by April 5, 1971.

Name (optional)________________________

Position______________________________

* Telecommunications is the sending and receiving of messages with artificial aids at a <u>distance</u>.

Form 1 (A [illegible])

Form A1

USDA-FOREST SERVICE

COMMERCIAL TELEPHONE DATA

(Check One) Data For Fiscal Year
☐ 1969
☒ 1970

(Check One and Fill in Name of Unit)
☐ Ranger Dist
☐ Forest
☒ Region)

Item	CCC's	Ranger District(s)	Supervisor Offices	Forest Total	Regional Office	Regional Total	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1. Number of commercial telephone instruments.	117	1,000	908	2,025	378	2,403	Av=$249/telephone/yr
	(SHOW ITEMS 2 THROUGH 6 TO THE NEAREST DOLLAR)						
2. Total company billings including instrument, toll, equipment, line and other charges for use of above telephones. NOTE: EXCLUDE FTS AND WATS COSTS INCLUDED IN ITEMS 3 AND 4 BELOW.	$ 35,283	$ 223,294	$ 109,987	368,564 $	$ 555	369,119 $	
3. FTS billings (Include here all off-net toll equipment, and service costs in connection with FTS service provided in item 1 above. (NOTE EXCLUDE ALL FTS BILLINGS FROM THE W.O.)	$	$ 2,873	$ 102,342	105,215 $	$ 80,834	186,049 $	
4. WATS and Special services billings (include WATS leased line, and any other special line costs used in connection with item 1 above).	$ 6,396	$ 5,617	$ 22,309	34,322 $	$ -	$34,322	
5. Non-recurring charges for equipment installations and change in connection with Item 1 above.	$ 656	$ 4,218	$ 2,903	$ 7,777	$ 866	$ 8,643	
6. Total of Items 2 through 5 above.	$ 42,335	$ 236,002	$ 237,541	$ 515,878	$ 82,255	$ 598,133	

Date 4/6/71

Date 4/6/71

Instructions: Complete one form each for F.Y. 1969 and 1970. If regular billings, tolls, and charges for equipment changes cannot be broken out by CCC, RD, and SO levels, show all under SO and explain in remarks. Form is usable at all levels.

Form A1

USDA-FOREST SERVICE COMMERCIAL TELEPHONE DATA	(Check One) Data For Fiscal Year [X] 1969 [ ] 1970	(Check One and Fill in Name of Unit) [ ] Ranger District [ ] Forest [X] Region

Item	CCC's	Ranger District(s)	Supervisor Offices	Forest Total	Regional Office	Regional Total	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1. Number of commercial telephone instruments.	111	942	759	1,812	376	2,188	Av=$255/telephone/yr
	(SHOW ITEMS 2 THROUGH 6 TO THE NEAREST DOLLAR)						
2. Total company billings including instrument, toll, equipment, line and other charges for use of above telephones. NOTE: EXCLUDE FTS AND WATS COSTS INCLUDED IN ITEMS 3 AND 4 BELOW.	$ 47,122	$198,274	$112,034	357,430 $	$ 949	358,379 $	
3. FTS billings (Include here all off-net toll equipment, and service costs in connection with FTS service provided in item 1 above. (NOTE EXCLUDE ALL FTS BILLINGS FROM THE W.O.)	$	$ 2,869	$ 76,832	$79,701	79,367 $	159,068 $	
4. WATS and Special services billings (include WATS leased line, and any other special line costs used in connection with item 1 above).	$ 2,263	$ 2,701	$ 24,576	$29,540	$ -	$ 29,540	
5. Non-recurring charges for equipment installations and change in connection with Item 1 above.	$ 6,471	$ 1,612	$ 2,092	$10,175	$ 478	$ 10,653	
6. Total of Items 2 through 5 above.	$ 55,856	$205,456	$215,534	$ 476,846	$ 80,794	$ 557,640	

Date 4/6/71

Date 4/6/61

Instructions: Complete one form each for F.Y. 1969 and 1970. If regular billings, tolls, and charges for equipment charges cannot be broken out by CCC, RD, and SO levels, show all under SO and explain in remarks. Form is usable at all levels.

USDA-FOREST SERVICE

Form A2

TOTAL EXPENDITURES FOR F.Y. 1969 AND 1970 FOR ALL CONSTRUCTION, MAINTENANCE, AND REPLACEMENT TO KEEP THE RADIO NETS OPERATING

([illegible] Show Name of Unit)

☒ Region)

Appropriation Responsibility		F.Y. 1969		F.Y. 1970
P&M 110	$227,340		$219,300	
P&M Other (list functions) 111	$91,000		$148,000	
1. 110 Structures,031,071	$50,764		$60,894	
2. 080,101,091,034,070	$		$	
3. 909,001,092,032,033	$		$	
4. 051,062	$		$	
P&M Subtotal		$369,104		$428,194
FR&T		$48,479		$61,215
State Coop.		$		$
Other Coop.		$4,995		$9,107
Brush Disposal		$58,142		$76,993
Other:				
Job Corps		$2,885		$2,639
CWFS Other,FFF,Sale Area Betterment		$1,655		$1,515
KV		$3,140		$7,296
		$ -1,640		$ 11,[illegible]
Total		$488,400		$586,959

(Note: Use form to obtain inventory from Forests and summarize by Regions.)

Date 4/6/71

Date 4/6/71

Form A3

USDA-FOREST SERVICE Region

INVENTORY OF ESTIMATED FINANCING REQUIRED TO BRING THE MAINTENANCE, REPLACEMENT AND CONSTRUCTION OF THE PLANNED REGIONAL TELECOMMUNICATIONS SYSTEMS UP-TO-DATE.

Based on existing Forest and Regional communications plans, please complete the following statements to be used for Service-wide telecommunications budgetary planning for F. Y. 1973.

1. An estimated lump sum of $500,000 would be required to bring the planned replacement of Forest nets, air nets, etc., up-to-date as originally planned.

2. An estimated annual sum of $316,000 will be required to keep the replacement program current assuming that it is brought up-to-date (Note - Use a ten year replacement cycle for estimating purposes).

3. An estimated annual maintenance budget of $795,000 will be required to maintain the planned systems once they are updated as outlined in the 1 and 2 above.

4. An estimated annual construction budget of $ 63,000 will be required to provide the additional telecommunication services needed. (Note - Base estimates on average annual construction requests received from field in F. Y.'s 69, 70 and 71.)

Note: Include salary for R. O. Electronic Engineer(s) in item 3, and allow for multi-functional assessments of all maintenance, replacement and construction funds at the R. O. level. Complete one form per Region.

Prepared by:	Approved by:
Date 4/6/71	Date 4/6/71

Exhibit B2

TELECOMMUNICATIONS QUESTIONNAIRE
FOR REGIONAL ELECTRONICS ENGINEERS

1. What is your expert advice for the number of preventive maintenance inspections per year required to keep the following equipment operating at peak efficiency with acceptable breakdown and downtime rates:

	Tube	Partly trans.	Substan. trans.	Solid state	
Fixed Station (locally installed)	4	4	3	3	Per year
Fixed Station (remotely installed)	4	4	3	3	Per year
Mobile	4	4	3	3	Per year
Portable heavy light	3	3	2	2	Per year

2. What work would you suggest be accomplished during a preventive maintenance inspection? (Add extra sheets if necessary) and (enclose any regional checklist or standard)

Return equipment to basic standard
(~~Ex~~ Sample ck list enclosed) EXHIBIT 1

3. What is the average time required to do a complete preventive maintenance for: (include only bench time)

a. Fixed base station 5 hours

b. Mobiles 4 hours

c. Portable (heavy) 3 hours

d. Portable (light) 3 hours

4. What percentage of their time, on the average, do radio technicians in your region spend on radio system maintenance, if the time spent on fire communications, equipment installation, maintenance of electrical equipment other than radio systems, etc., is subtracted from total time?

63 (% of total time)

Form B

5. Considering the percent of time available for radio maintenance, how many radio units, on the average, can a competent radio technician service? 120 (units)

6. How long, on the average, do you keep a radio before replacing it?

a. Fixed base station 16 years (Because of finances)

b. Mobiles 15 years

c. Portables (heavy) 13 years

d. Portables (light) 13 years

e. Repeater 13 years

7. Do you think fixed replacement schedules are required for:

	Don't know	Yes	No
Tube equipment	/7	X	/7
Partially transistorized	/7	X	/7
Substantially transistorized	/7	X	/7
Solid state	/7	X	/7

8. What would your expert advice be for replacement schedules for:

	Tube	Partly trans.	Substan. trans.	Solid state	
Fixed Station (locally installed)	10	10	10	10	Years
Fixed Station (remotely installed)	10	10	10	10	Years
Mobile	8	8	8	8	Years
Portable heavy light	8	8	8	8	Years

9. What factors led you to decide on the answers in question #8 (e.g., increased maintenance costs, failure rates, unavailable parts, personal experience, obsolescence, etc.)?

(1) OBSOLESCENCE (2) UNAVAILABLE PARTS
(3) PERSONAL EXPERIENCE (4) INDUSTRY STANDARDS

10. Can you support the use of the above factors with facts and figures?

/_/ Yes /_/ No /X/ Some (specify) ~~B~~ 1962 Base Station ~~St~~ Chassis are not ~~Ava~~ Available now —

11. What would your opinion be concerning flexible replacement schedules: (i.e., a formula or computer readout that predicted the replacement date for specific equipment or types of equipment based on factors such as maintenance cost, failure rates, etc.).

/_/ Very worthwhile

/X/ Would be only marginally beneficial

/_/ No benefit

/_/ Would cost much more than a preset schedule based on experience and judgment

Any comments: We don't need an automatic red flag to tell us when equipment should be replaced ~~##~~ unless all records go ADP it could be ~~lever~~ handy

12. When you replace a still functioning radio with a new unit, what do you do with the old unit? Sell or use in another System to up-date with newer old equipment.

13. If you sell old (obsolete) units, what price do you get, on the average, for:

a. Fixed base station $ 35.00

b. Mobiles $ 15.00

c. Portables $ 8.00

14. What, in your judgment, are acceptable breakdown or failure rates for:

	Summer	Fall	Winter	Spring	
Fixed Station (locally installed)	.5	.5	1	.5	per season
Fixed Station (remotely installed)	.5	.5	1	.5	per season
Mobiles	1	1	2	1	per season
Portables	1	1	2	1	per season

15. What, in your judgment, are acceptable downtime (average time to return the equipment to service) for:

	Summer	Fall	Winter	Spring	Ave Days & fract.	
Fixed Station (locally installed)	1	3	5	3	3	days
Fixed Station (remotely installed)	1	3	5	3	3	days
Mobiles	2	5	10	5	5½	days
Portables	2	5	10	5	5½	days

16a. How many "swing" sets would be required to reduce your annual maintenance budget by:

	Fixed Stations	Mobiles	Portables
10%	X	2/FOREST	1/DISTRICT
25%	X	??	??

16b. Any comments on "swing" sets: Swing sets are only Partially effective — after a basic need more swings would ~~just~~ ~~to~~ increase the work Load —

17. What data about on-going maintenance would you require in order to determine and analyze the effectiveness of your maintenance policies?

(1) PREVENTIVE MAINTENANCE SCHEDULE (2) BREAK DOWNS (CAUSE) (3) PARTS COST (4) TRAVEL COSTS (5) MAINTENANCE TIME

18. What data would you require to determine or analyze how well your equipment specifications are meeting your needs?

The needs and requirements dictate equipment Specification

SPEC - Philosophy
1. SPECify only what you want & need
2. Don't Specify more than you are prepared to inspect.
3. Write specifications so they Cannot be misunderstood.

19. Would the benefits of the ability to analyze maintenance and/or equipment specification effectiveness outweigh the cost to analyze and gather the data?

/_/ Yes /_/ No

Comments; Not sure — I believe when down-time, reliability, etc are set maintenance and equipment standards will be automatic.

20. What is the average annual maintenance and repair cost breakdown for the equipment listed below by age group? (Assume all work is done in house with F.S. employees.)

Equipment (new) (0-7 yrs. of age)	Labor incl. travel & per diem	Parts	Total
a. Fixed base station	170	16	186
b. Mobile	115	16	131
c. Portable (heavy)	90	10	100
d. Portable (light)	90	10	100
e. Repeaters (battery)	100	10	110
f. Repeaters (A.C.)	170	16	186
g. Radio links	170	16	186

Do not actually have costs ~~et~~ per unit etc. From our maintenance log could get Fair figures - Parts level-off #14/radio

Equipment (old) (0-7 yrs. of age)	Labor incl. travel & per diem	Parts	Total
a. Fixed base station			
b. Mobile	Est. increase of 15%		
c. Portable (heavy)			
d. Portable (light)			
e. Repeaters (battery)			
f. Repeaters (A.C.)			AB
g. Radio links			

21. What is the average operating cost per year (incl. power, batteries, inventory, shop space and administrative costs, but excluding maintenance cost and wages of radio operator) for:

a. Fixed base station $ 110

b. Mobiles $ - 0 -

c. Portable (heavy) $ #10 (new) #30 (old)

d. Portable (light) $ #12 (new) #25 (old)

2000 300

22. What is the average installation cost in your region for:

a. Fixed base station, remote $ 4000 [building - tower - hardware Labor, etc]

b. Fixed base station, local $1000 [towers, hardeware, labor]

c. Mobiles $35 to $45

d. Repeaters (battery powered) $2500 [Thermal generator installation] [NO BUILDING]

e. Repeaters (A.C.) $ 4000 [building - tower - hardware labor]

f. Radio links $ 4000 [building - tower - " "]

23. What is the average annual period of use of radio equipment in your region? 10 (months per year)

[mobile-Base (year-long) Portable 8 + (Most repeaters year-long)]

24. If you have contracted field maintenance recently (5 years), please attach a copy of specifications used in the contract.

EXHIBIT II

a. Are you satisfied with the results? [ ] Yes [x] -PARTLY [ ] No

b. If your answer above was no, please give reasons.

*The tech ~~[illegible]~~ AVAILABILITY ~~[illegible]~~ IS NOT Satisfactory to FOREST (Communications mgt. is needed)

25. What do you see as future needs for telecommunications and electronics in Forest Service programs?

Coordination of all present uses and provide ~~ing~~ Service for future needs - (1) Communications (2) Teletype (3) ADP Services (4) Computer access At least on a Regional Basis - I am not sure it would be feasible on Service wide basis.

Exhibit B3 Sample forests and districts which responded to the General Telecommunications Questionnaire.

Region 1.

Custer N.F.
- Beartooth R.D.
- McKenzie R.D.

Flathead N.F.
- Spotted Bear R.D.
- Glacier View R.D.

Kaniksu N.F.
- Priest Lake R.D.
- Newport R.D.

Nezperce N.F.
- Salmon R.D.
- Selway R.D.

Region 2.

Black Hills N.F.
- Custer R.D.
- Pactola R.D.

Roosevelt N.F.
- Poudre R.D.
- Pawnee R.D.

San Juan N.F.
- Glade R.D.
- Piedra R.D.

White River N.F.
- Aspen R.D.
- Blanco R.D.

Region 3.

Cibola N.F.
- Magdalena R.D.
- Sandia R.D.

Coconino N.F.
- Long Valley R.D.
- Beaver R.D.

Gila N.F.
- Silvercity R.D.
- Reserve R.D.

Region 4.

Boise N.F.
- Idaho City R.D.
- Garden Valley R.D.

Fishlake N.F.
- Kanosh R.D.
- Beaver R.D.

Teton N.F.
- Buffalo R.D.

Toiyabe N.F.
- Alpine R.D.
- Bridgeport R.D.

Wasatch N.F.
- Evanston R.D.

Region 5.

Klamath N.F.
Salmon River R.D.
Goosenest R.D.

Los Padres N.F.
Monterey R.D.
Santa Barbara R.D.

San Bernardino N. F.
San Jacinto R.D.
Cajon R.D.

Tahoe N.F.
Downieville R.D.
Truckee R.D.

Region 6.

Gifford Pinchot N.F.
Mt. Adams R.D.
Randle R.D.

Mt. Hood N.F.
Clackamas R.D.
Zigzag R.D.

Wallowa Whitman N.F.
Chesnimnus R.D.
Pine R.D.

Wenatchee N.F.
Leavenworth R.D.
Entiat R.D.

Willamette N.F.
Detroit R.D.
McKenzie R.D.

Region 8.

NFS in Florida
Lake George R.D.
Seminole R.D.

George Washington N.F.
Deer Field R.D.
Pedlar R.D.

Ouachita N.F.
Caddo R.D.
Oden R.D.

NFS in North Carolina
Pisgah R.D.
Wayah R.D.

Region 9.

Huron Manistee N.F.
Manistee R.D.
White Cloud R.D.

Superior N.F.
Gunflint R.D.

Mark Twain N.F.
Doniphan R.D.
Willow Springs R.D.

White Mountain N.F.
Pemigewasset R.D.
Saco R.D.

Exhibit B4

TELECOMMUNICATIONS* QUESTIONNAIRE

FOR FOREST SUPERVISOR

The_______________Forest has been selected to assist the Forest Service Telecommunications Study Team. They need your answers to prepare recommendations for improved communications.

Please relate your answers to calendar year 1970. Give your estimates only. No detailed analyses are required.

Please list the Ranger Districts that will answer questionnaires 3 and 4:

District A ____________________

District B ____________________

Also complete the District entry on the title page of the 6 questionnaires in the District packages.

This questionnaire (Form 2) is in two parts - 1 through 19, a general section, and questions 20 - 29 specifically for the radio technicians.

Please answer all questions as completely as possible. Attach extra continuation sheets if necessary. If you have any questions, contact the Management Sciences Staff in Berkeley, California.

The self-addressed envelope should be used to mail the questionnaire by April 5, 1971.

Name (optional)____________________________

* Telecommunications is the sending and receiving of messages with artificial aids at a <u>distance</u>.

Form 2

TELECOMMUNICATIONS QUESTIONNAIRE

FOR SUPERVISORS OFFICE

1. There are many possible methods to finance the cost of radio communications. As a manager, give your preference rating in order of priority from 1 to 5.

V /5/ Line item - Fire and General Improvements

W /3/ Line item - Radio Communications

X /5/ General Operations Expense

Y /2/ Working Capital Fund

Z /3/ Other (specify below)

Please explain why: Line item -- based on Area Planning w/ Replacement Schedule

2. Is it desirable that your regional communications committee should approve:

/ / All communication needs?

/X/ Major communication needs only (for investments in excess of 350 dollars).

/ / None of your communication needs.

3. If you transmit or receive non-voice information now, complete the table below:

Type of Information (telemetry, data, maps, etc.)	Origin (field, Dist. or S.O.)	Means of Transmission (leased lines, microwave, etc.)
A. TeleType	R.O.	Leased Lines
B.		
C.		

4. What changes do you foresee in your information transmission needs within the next 2 or 3 years?

Explain: Climatological Telemitry (remote sensing) system added to the system. This would be a seperate system. Tie ADD'L Radio Net into Tw. Districts. Ranchers have Sep. Net & they are part of Fire Det system.

5. Do you now have leased line (inter-com) service to district offices?

[ ] Yes [X] No

6. If you have leased line system, is it satisfactory in cost and service?

[ ] Yes [ ] No

Explain: N/A

7. Do you have leased line communications (other than FTS) with any other points within or without your forest?

TeleType

8. Is the airnet used regularly to communicate with points outside your forest -

for busy season only:

[X] Airborne aircraft use only

[X] Aircraft ground support

[ ] General administrative use

[ ] Other:

for off season:

[X] Airborne aircraft use only

[ ] Aircraft ground support

(continued next page)

/_/ General administrative use

/_/ Other: ____

9. List the positions (or crews) in the Supervisor's office which need their own radio communications when in the field. (Examples: contracting officer, repair or survey crews, fire control officer, etc.) Indicate whether they do or do not have such communications at present: Fire Staff Has

Three Survey Crews HAVE

Five Project ENGRS HAVE

ADMINISTRATIVE STAFF HAS

COMMUNICATIONS Tech ~~Has~~ HAS

* 10a. Do you frequently cooperate with adjoining (or other) forests in the use of radio equipped tanker trucks and other equipment for use in fire suppression?

/_/ Yes /X/ No

* 10b. What are your communication needs between adjoining forests in fire suppression: Telephone & Teletype

11. If you used fire cache radios last year, what was the elapsed time from request to delivery for the following caches:

Zone cache	____	hours
Regional cache	6	hours (EST.)
Inter-Regional (BIFC)	____	hours

* Cooperate w/ STATE of SOUTH DAKOTA ON STATE NET. & RANCHERS ON TWO DISTRICTS ARE FORMING OWN ~~FM~~ NET, RANCHERS ARE PRIME FIRE DETECTORS AND CREWS. WE WILL NEED COMM. WITH THEM.

12. Do your present communication facilities hamper your effectiveness in initial fire suppression activities?

/_/ Yes /X/ No , if in good order

If yes, what is the value of the loss sustained in 1970 due to this deficiency?__________(estimated dollars) What improvements are needed to rectify this situation?

13. Does current communication planning reflect actual needs generated by long-range (3 yr.+) resource and/or functional needs?

/_/ Yes /X/ No

14. If you answered no, how can we best integrate these long-range needs into communication planning? Presently Long Range Planning is in State of Flux. Communication Planning must be a part of Annual Long Range Planning Effort. This is not a problem presently

15. How often do you use or refer to the communication plan for your unit?

Times per year: 3

16. Do the standards in FSM 7222 meet your needs for communication planning?

/X/ Yes /_/ No

17. What specifically should be added to your plan to make it a more effective management tool? Should be a part of Long Range Planning and Should be reviewed annually at Mid year.

18. How often should your communication plan be revised?

Every * 2. years

* See #14

19. How deeply is the forest involved in communication planning?

- /_7 Not at all
- /_7 Minor contributor
- /X7 Major contributor
- /_7 Responsible for plan preparation

THE FOLLOWING QUESTIONS SHOULD BE ANSWERED BY THE ELECTRONICS TECHNICIAN FOR THE DISTRICTS NAMED ON THE COVER SHEET:

~~20.~~ What is the age of most radio sets on the districts? 11 years

21. Where are the radio sets mounted on their vehicles? (Show how many vehicles for each location.)

Sedans

Dist. A	Dist. B	
		dash
		under hood
		under seat
		in trunk
1		other (specify)

Back seat of sta. wgn

Pickups & Trucks

Dist. A	Dist. B	
		roof
2	3	under hood
1		truck bed
		under seat
		fender
		dash
1	1	other (specify)

Tool Bx

22. What is the coverage for District A 90 %

B 95 %

23. Is your forest system a one or two channel system?

/ / One /X/ Two

24. Are the sampled districts unusual in type, number, use or age of communication equipment compared to your other districts?

/ / Yes /X/ No

If yes, explain: ______________________

25. What kind of radio maintenance records do you keep?

/_7 None

/_7 Preventive maintenance performed

/✓7 Breakdowns and preventive maintenance, no downtime

/_7 Breakdowns and preventive maintenance, including downtime

26. What are your current preventive maintenance schedules for:

Portables: 12 Month

Mobiles: 3 "

Base Stations: 3 "

Remote Consoles: 6 "

Repeater Units: 3 "

Why did you adopt this schedule? Time period seems sufficient to prevent most breakdowns and keep equipment at rated performance level.

27. What are the average failure rates per year by classes for:

Base Stations: 1

Mobiles: 2 to 4

Portables: 2

28. What is average downtime from breakdown to restoration for these three classes?

Base Stations: 1 to 3 days if parts in stock.

Mobiles: same

Portables: same

29. What are the radio interference problems on your forest?

Extremely bad interferrance from TV channel 2 at S.O. Billings. No other problems on balance of forest.

Exhibit B6

TELECOMMUNICATIONS* QUESTIONNAIRE

for District Ranger

The ____________________ District has been selected to assist the Forest Service Telecommunications Study Team. They need your answers to prepare recommendations for improved communications.

Please relate your answers to calendar year 1970. Give your best estimates only. No detailed analyses are required.

Questionnaire Number 4, District Staff and Foremen, should be answered by two of your foremen and three of your professional staff, if possible. Please show the position or title of those selected to make the reply (names are not necessary).

1. FORESTER ASST RGR GS-11
2. FORESTER ASST RGR GS-9
3. FOR TECH - F CO GS-7
4. FOR TECH GEN GS-7
5. FOR AID GEN GS-4

Please answer all questions as completely as possible. Attach extra continuation sheets if necessary. If you have any questions, contact the Management Sciences Staff in Berkeley, California.

The self-addressed envelope should be used to mail the questionnaire by April 5, 1971.

Name (

* Telecommunications is the sending and receiving of messages with artificial aids at a distance.

Form 3

TELECOMMUNICATIONS QUESTIONNAIRE

List for the district:

The total number of PFT employees	14
Peak number of temporary employees	12 ① 14
Number of crew foremen	4
Number of principal staff	3
Number of clerical employees	2
District Budget for FY 1971	$ 169,000 RDMA CLERICAL ~~PROJECT~~ PROJECT

① THERE ARE 14 POVERTY WORKERS (OPERATION MAIN STREAM) SUPERVISED BY A PFT GS-5 CREW-FOREMAN.

List total number of radios in use on your district by category:

	Forest (District) Net	Special Nets
Number of base stations	1	-
Number of repeater stations and links	1	-
Number of mobiles	8	-
Number of heavy portables	3	-
Number of light portables	9	2

The special networks in use on your district are:

AIR NET

Positions, areas, activities on your district which need to be covered for periods longer than the regular work hours:

Position, Area or Activity:	Reasons for required coverage:
FIRE CONTROL	PROTECTION
RECREATION	LARGE REC. COMPLEX 1/4 MILLION VISITS /EARLY

TELECOMMUNICATIONS QUESTIONNAIRE

1. For those activities shown in the table in which you were an active participant, complete columns 3 through 13, using the following guides:

Column (3) The average crew size (including yourself) on that particular activity.

Column (4) Total pay periods or fractions thereof spent on activity by you and your crew during calendar year 1970.

Column (5) Number of radios you had with you on activity ("0" if without radios). State whether equipment portable PL light, PH heavy, mobile M, or other wype.

Column (6) State what, if any, other means of telecommunications you had available on that job (telephone, radio-telephone, etc.).

Column (7) Estimate the percentage of your telecommunications on job transmitted over radio (100%, 90%, 0%, etc.).

Columns (8), (9), and (10)

Enter your best estimate of the usual number of calls per pay period on this activity placed by you and/or your crew members.

Column (8) Administrative: reporting time or equipment use, etc.

Column (9) Project work related: instructions, ordering equipment and/or supplies, etc.

Column (10) Fire related: fire standby, fire weather, fire instructions, fire reporting, etc.

Column (11) How many calls did you and crew receive during same period in activity?

Columns (12) and (13)

Do not complete these columns until after you have finished questions 2 through 6. Rate the value of radios separately for activity accomplishment only (Column 12) and fire stand-by only (Column 13), even if you did not have the use of a radio on a job, according to the following scale:

	Code
Must have radio on this job:	1
Radio very important on this job:	2
Radio important on this job:	3
Radio convenient:	4
Radio unnecessary	5

Question 1, continued

Activity Group (1)	Activities (2)	Av. Crew Size (3)	Time Spent on Activ. (Pay Period or fract.) PAY PERIODS (4)	Nbr. & kind of radios on job with you (5)	Other comm. equip. available (6)	Calls transmitted over radio (%) (7)	Approx. number of calls placed Per Pay Period: Admin. Calls (8)	Activ. Calls (9)	Fire Calls (10)	Approx. number of calls rec'd per pay period (11)	Value of radios for Activ. (Use code) (12)	Value of radios for fire standby (Use code) (13)
	Layout work & inspection of crews											
Activity Group I	Timber Sales Prep.	4	1½	1 M 1 LP		5	2	2		2	3	1
	Timber Sales Adm.	1	1	1 M		10	3	6		4	2	1
	Timber Surveys	1	½	1 M		5				1	4	4
	Reforestation SAME	6	1	1 M 1 LP		15	2	2	10	2	3	1
	TSI											
	Range Analysis	/										
	Range Reveg.	/										
	Range Structures	/										
	Rec. Op. & Mtc.	8	3	2 PH 2 PL		20	5	15		6	2	1
	Rec. Dev.				Teleph							
	Adm. of wilderness	/										
Activity Group II	Law Enforcement (incl. all trespass)	2	1	2 M	Teleph.	50	-	10		4	1	1
	Watershed Inv.	1	½	1 M		5	5	10			4	4
	Watershed Restor.	6	½	1 M		10	10	15		1	3	1
	Wildlife Inv.	1	½	1 M		5	1	1		1	4	4
	Wildlife C&M	6	1	1 M		10	1	5		4	3	1
	Land Uses	1	2½	1 M		15		10		6	2	1
Activity Group III	Fire Pre-supp.		4	8 M 6 LP		80	10		80	40	1	1
	Insect & Dis. Con.	/					1			1	4	1
	C&M of Adm. Imp.	4	1	1 M		5	2	4		3	3	1
	Roads & Trails Mtc.	4	1	1 M 1 PL		5	2	2		4	3	1
	Const. & Pre-Const. R&T	6	1	1 M 1 PH		5	2	4		3	3	1
	General Admin.	1	6	3 M 3 LP	Teleph	50	6	40		20	1	1

2a. Select one activity representative of your major effort in 1970 within each activity group in the table on page 2 (activity groups I, II, and III) and show:

Activity in Group I : TIMBER SALES ADM

Activity in Group II : LAND USES

Activity in Group III: GENERAL ADM

Average travel time to Activity I: 45 (minutes)

If meaningful, show average travel times for:

Activity II: ______ (minutes)

Activity III: ______ (minutes)

Average estimated travel time to nearest means of communications other than your radio when engaged in

Activity I: 30 (minutes)

Activity II: 20 (minutes)

Activity III: 30 (minutes)

2b. For each of the activities selected in question 2a, consider the direct savings or losses in time to you and/or your crew members due to the use of radio communications. Estimate the frequency of occurrence for the items listed below which apply to your situation:

	Frequency per pay period		
	Activ. I	Activ. II	Activ. III
Reporting, such as time and attendance, while traveling to or from work rather than making special stops for this purpose.	1	0	0
Making crew assignment, etc., as above.	1	1	0
Saving travel time by eliminating some trips to or from the project area (this may be related to being able to consult over the radio about an unforeseen or new situation).	2	3	5

	Frequency per pay period		
	Activ. I	Activ. II	Activ. III
Saving time by prearranging for the availability of supplies (delivery of pre-mixed concrete, etc.) so that crews would not be delayed.	3	1	5
Expediting the contractor jobs by keeping in closer touch over the radio.	2	2	1
Other. (List additional time savings/losses, which occur in your work due to use/lack of radios):			
________			
________			
________			
________			
________			
________			
________			
________			

2c. Give your estimates of the time saving due to the use of radios for each of the three representative activities noted in question 2a if you have had radio communications available:

Time savings to yourself, due to radio use, per pay period:

Activity I 2 (hours) 0 (minutes) per pay period

Activity II 1 (hours) 30 (minutes) per pay period

Activity III 2 (hours) 30 (minutes) per pay period

Time savings to crew members, due to radio use, per pay period:

Activity I 2 (hours) 30 (minutes) per pay period

Activity II 0 (hours) 30 (minutes) per pay period

Activity III 2 (hours) 0 (minutes) per pay period

2d. Estimate overall time lost, if any, through unnecessary or overly long radio communications:

Activity I ___0___ (hours) ___15___ (minutes) per pay period

Activity II ___0___ (hours) ___15___ (minutes) per pay period

Activity III ___0___ (hours) ___30___ (minutes) per pay period

3a. How often during the last year did you go yourself or send someone with a message to people without a radio? I did so ___2___ (number) of times. I estimate the total time expended specifically on this effort to be ___150___ (minutes), worth ___5.75___ (dollars). Most often involved were:

FIRES - LOCAL NAT. FOREST FIRE WARDENS OR STATE ...

ARRIVED ON FIRE BEFORE DIST. PERSONNEL.

THESE MEN TOOK ACTION ON ARRIVAL.

3b. How often during the same period of time did you receive in the field a message delivered by someone in person because radio communications were not available? I received ___3___ messages. I evaluate the total time expended specifically on this effort (i.e., had to make a side trip or special trip) to be ___50___ (minutes), worth ___40___ (dollars).

4a. Consider benefits other than direct time savings due to the availability of radios which apply to your routine day to day operations, such as:

Need fewer men to accomplish job;

Avoid idle time in activity by being able to seek new instructions;

Can operate more efficiently during high fire danger periods;

Save on mileage by reducing the number of required trips, etc.

List those benefits/losses, including the examples listed above, arising from the availability/non-availability of radios which are important to your work:

ALL 4 EXAMPLES ABOVE

4b. Give your estimates of the total value of the benefits from the availability of radios for the three representative activities selected in question 2a during 1970:

Estimates of benefits from use of radios in 1970:

Activity I $1,000 dollars

Activity II $300 dollars

Activity III $2,500 dollars

NOTE: Please return to question 1 to complete columns (12) and (13) of table on page 2

5. Estimate savings in telephone toll charges for your District because radio is available and used instead of the telephone 350 (dollars per year).

6. List the projects and/or activities in your district in the order of greatest benefit derived from radio communications. Start with activity deriving highest benefit.

1. FIRE CONTROL
2. GEN. ADM
3. LAW ENFORCEMENT
4. REC. Op & Maint
5. TBR SALES ADM
6. REFORESTATION & TSI
7. WILDLIFE C & M
8. LAND USES
9. ROAD & TRAIL MAINT
10. WATERSHED RESTOR.
11. TIMBER SALES PREP
12. C & M OF ADM IMP.
13. INSECT & DIS CONTROL
14.

7. List the places or people (by position) you call in order of the importance of such calls to you. For each item, give your estimate of the number of calls per week during the busy season.

	Place or Position	No. Calls per Week
(1)	OFFICE - CLERK DISPATCHER	10
(2)	LAND USE - ASST RGR	5
(3)	F. C. O.	5
(4)	C & M FOREMAN	2
(5)		
(6)		
(7)		
(8)		
(9)		
(10)		

8. List places or people you should be able to communicate with over the radio network but are presently unable to do so because of lack of radios or poor coverage. Estimate the losses arising from this inability to telecommunicate.

a. SUPERVISORS OFFICE
NO GREAT LOSS

b. FIRE CONTROL STAFF OFFICER
NO GREAT LOSS

c.

d.

9. Did you use radio communications during 1970 in emergency situations involving personal safety (exclude fire if no specific safety hazard existed)?

/X/ yes /_/ no

If your answer is yes, how often? 4

How did communications facilities, or the lack of them, contribute to the situation?
1 - Game Law Violation — radio call to office & phone call to Warden [illegible]
1 - Auto Accident - radio call to office then phone call out
State Police there quicker
2 - LOST PERSONS - Assisted greatly in coordination of
search

10a. How often did you get called to a fire while you were in the field during all of 1970? 3 What is your estimate of the time savings due to the availability of radio for all these calls, taking into consideration that the disposition of forces would be different without radios:

15 (hours) 30 (minutes)

10b. How often during 1970 were you unable to relay important fire or other emergency information over the radio because:

(1) You had no radio ______ (number times)

(2) Other end had no radio 1 (number times)

(3) Insufficient area coverage 1 (number times)

What is your estimate of the direct losses due to this inability to communicate? $1000 (dollars)

11. Did you suffer delays due to congestion of your radio channel in 1970? If so, how frequently and under what circumstances?

/_/ All year

/_/ Throughout busy season which extends from ______ to ______

/_/ Entire length of incident or day

/_/ Good part of day or incident

(continued on next page)

/7 Fire only

X Fire and high fire danger periods only

/7 Few days during year, mostly related to emergency situations

/7 Not at all

/7 Short period only, usually during ____________________

____

____

12. Do you have radio communication coverage for most of your important work areas?

X yes /7 no

If not, what do you estimate the resulting losses to have been during 1970? ______________________________ (dollars)

____

____

13. Do the district radio communications limit your ability to fully utilize your men during high fire danger rating periods?

/7 yes X no

What is your estimate of the dollar value of this limitation measured against full utilization if perfect communications were available?

__________(dollars/year)

What would be required to remove this limitation? ________________

____

____

14. Do you have on the district radio capability to direct air tanker drops for initial attack?

X yes /7 no

How many times did you use this capability last year? 1

15a. What are the busiest times of day on the radio channel during non-fire periods? from 0500 to 0900 and from 1600 to 1700.

15b. Which statement describes your actions best when you want to make a call and the line is busy?

You monitor the radio traffic over your channel continuously in order to get on immediately after the channel clears in:

/_7 no instance

/X7 a few instances (fewer than one-quarter)

/_7 a moderate number of instances (about one-quarter)

/_7 about one-half of the instances

/_7 about three-quarters of the instances

/_7 most of the instances (about nine-tenths)

/_7 always

15c. When you wish to place a call and find the channel busy, and you don't monitor the channel continuously, your actions are best described by:

/_7 I monitor intermittently for a period of (about) ______ minutes and then stop and try again later (in about ______ minutes).

/X7 I forget it immediately and try later (in about 5 minutes).

/_7 Other (please describe) ____________________________

16. Do you find it necessary to monitor the forest (district) net to keep informed about the general situation?

/X7 Yes, I do need to monitor the forest (district) net.

/_7 I like to monitor the forest (district) net but it is not very important that I be able to do so.

/_7 No, I do not need to monitor the forest (district) net.

17. Under conditions of no going fire, high fire danger, and need to make non-fire calls on your radio, what are acceptable delays in getting a free channel for most (90%) of your non-fire calls?

- /7 one minute
- /7 two minutes
- /7 three minutes
- X five minutes
- /7 ten minutes
- /7 other ____________

18. With a going fire, what are the district's delay time requirements for fire related communications?

- /7 less than one minute
- /7 one minute
- /7 two minutes
- X three minutes
- /7 five minutes
- /7 ten minutes
- /7 other ____________

19. How deeply are you involved in communication planning for your unit?

- /7 Not at all
- X Minor contributor
- /7 Major contributor
- /7 Responsible for plan preparation

20. How often do you use or refer to the communication plan for your unit?

2 times per year

21. What specifically should be added to your communication plan to make it a more effective management tool?

$ for putting mobiles in all vehicles expect dump trucks & etc
Built in receiving & transmitting head gear for fire plow operator

22. Does current communication planning reflect actual needs generated by long-range (3 yr.+) resource and/or functional needs?

/_/ yes /X/ no

23. If you answered no, how can we best integrate these long-range needs into communication planning?

Dollars to implement plan.

24. Does the forest electronics technician periodically schedule preventive radio maintenance for your district?

/X/ yes /_/ no /_/ don't know

a. If yes, how often? /_/ 1 time/year /X/ 2 times/year

/_/ 3 times/year /_/ 4 times/year

b. Does he do the preventive maintenance at the district /X/ ~~or~~ AND in his shop /X/? Don't know /_/.

25. What is the average length of time the technician spends on your district's equipment for each scheduled preventive maintenance?

/_/ 1 day /_/ 2 days /X/ more than 2 days /_/ don't know

26. When you fail to establish or complete a radio message, what is the cause most of the time?

/_/ Lack of radio coverage (can't get out)

/X/ Radio equipment failure

/_/ Other (specify)______________________________

27. Estimate the number of times in the last 6 months the radios you have used malfunctioned while you attempted to use them.

Fixed : /_/ None /X/ 1 time /_/ 2 times /_/ more than 2 times

Mobile : /_/ None /_/ 1 time /X/ 2 times /_/ more than 2 times

Portable: /_/ None /_/ 1 time /_/ 2 times /X/ more than 2 times

28. Estimate the average length of time it takes to get your high priority radios back in service after breakdown.

1 (number days)

29a. How many breakdowns of your radio during each season would you consider unacceptable?

Summer: more than 2 (breakdowns)

Fall : more than 1 (breakdowns)

Winter: more than 2 (breakdowns)

Spring: more than 1 (breakdowns)

29b. What would you consider an unacceptable downtime?

Summer: over 16 (hours downtime)

Fall : over 12 (hours downtime)

Winter: over 16 (hours downtime)

Spring: over 8 (hours downtime)

29c. If your radio is out longer than one day, what are the remedial actions taken:

/X/ Get lower priority use radio

/_/ Use "swing set"

/_/ Go without

/_/ Other ______

30. What percent of your district has radio coverage during:

The busy season		The off season
/X/ 30%	WITH PORTABLE	/X/ 30%
/_/ 50%		/_/ 50%
/X/ 75%	WITH MOBILE	/X/ 75%
/_/ 90%		/_/ 90%
/_/ over 90%		/_/ over 90%

31. If you indicated reduced coverage during the off season, give reasons:

/7 Discontinued lookouts

/7 Shut down repeaters and/or remote base stations

/7 Stop servicing repeaters and/or remote base stations

/7 Other ______________________________

32. What is the general quality of reception you have in the district areas covered?

/7 Barely intelligible

/7 Intelligible

/X/ Good

/7 Excellent

33. State your most urgent and, as yet, unsatisfied communication need on the district. If none, say so.

FIRE PLOW OPERATOR HAS TO STOP OPERATING DOZER TO TALK ON RADIO, HARD TO HEAR OVER MOTOR NOISE

34. What are the potential benefits which, in your judgment, would result from satisfying this need? Please be specific.

SAFETY - RADIO HOOK UP BUILT INTO CRASH HEMLET WOULD PERMIT OPERATOR TO WARNED of HAZARD & HE WOULD NOT HAVE TO SHUT DOWN TO HEAR RECEIVER

35. If possible, estimate the dollar value per year of the benefits listed above: HARD TO ESTIMATE (dollars).

$500 to $2500 Depending on Use.

36. If your message quality is only intelligible or barely intelligible, what is the reason?

X Voices are strong but distorted and difficult to understand

/_/ Voices are weak and noisy

/_/ Voices are weak and break in and out

37. The following messages are presently represented in one or more of the various code systems. In the "NEEDED" column, check (✓) those messages you feel definitely need a code assignment because of their importance and consistent use; in the "NOT NEEDED" column, check those you feel need not be codified (because, for example, the words themselves are sufficient or clearer than a code). Check only one column for each message. If you have no opinion on a specific message, leave blank

NEEDED	NOT NEEDED	
✓		Unable to copy; change location
	✓	Finished last assignment
✓		Arrived at the scene
	✓	Request radio serviceman to be set to -
	✓	Have you dispatched -
	✓	Confine message to official business
✓		Call my home
	✓	Proceed to -
	✓	I am now ready to take information
✓		Standby; am proceeding to better location
	✓	Use code
		Turn off automatic repeater
		Turn on automatic repeater
	✓	Advise if - available for call
✓		What is the correct time
✓		Emergency traffic this station
✓		Routine check-in
✓		Do you have contact with -
	✓	Standby
✓		Standby, will return your call
	✓	Disregard last message
	✓	Call dispatcher by phone
✓		What is your location
✓		Return (or I am returning) to station
✓		Weather
		Officials or visitors present
	✓	Transmitting too rapidly
	✓	Out of service, at home; subject to call
	✓	Repeat
✓		In service
✓		Out of service
✓		Verbal repeat

(Continued on next page)

NEEDED	NOT NEEDED	
✓		O.K. (verbal acknowledgment)
		Stop all radio traffic
✓		Receiving well
✓		Receiving poorly
	✓	Brush Fire
	✓	Forest fire
	✓	Grass fire
	✓	Structure fire
	✓	Illegal fire or incendiary
	✓	Plane fire
	✓	Vehicle fire
	✓	Traffic conditions, need Highway Patrol
		Can handle
	✓	This is legal permit burn
	✓	Need FS investigator
✓		Report on conditions
	✓	Check smoke
✓		Off air at the scene
		Under control
		Air is clear; resume transmitting
✓		All clear; no fires
	✓	What is (or this is) the burning index
		Leaving base on patrol flight
		Arrived base on patrol flight (returning base)
✓		I have (or do you have) fire traffic
		Take my subsistence order
		Emergency fire call
		We have no traffic for you
✓		How is reception
		What is the fire condition

38. For messages where the word equivalent could be made almost as brief as a code (e.g., 10-48 vs. "go ahead" instead of "I am ready to take information") which do you prefer:

[X] Code   [ ] Word

Why? LESS CHANCE OF BEING MISUNDERSTOOD, PEOPLE SOON DEVELOP THEIR OWN VERSION & TEND TO TALK MORE.

39. How many codes can you readily remember?

Less than 10	[ ]	31 - 40	[ ]
11 - 20	[X]	41 - 50	[ ]
21 - 30	[ ]	Over 50	[ ]

MORE IF I HAD TO - I KEEP 3X5 CARD IN POCKET FOR QUICK REFERENCE

40. Should we eliminate the use of codes altogether?

[ ] yes   [X] no

If no, explain CODES ARE BRIEF - KEEPS TRAFFIC DOWN

41. Which codes do you personally use:

	Adm. Traffic	Fire Traffic
Ten code	[X]	[X]
Four code	[X]	[X]
Nine code	[ ]	[ ]
Other (identify):________	[ ]	[ ]

42. Would it be advantageous and practicable to combine all necessary codes under one code system?

Explain: YES IF THEY WERE ARRANGED FOR EASY MEMORY

Exhibit B7

TELECOMMUNICATIONS* QUESTIONNAIRE

for District Staff & Foremen

The ______________________ District has been selected to assist the Forest Service Telecommunications Study Team. They need your answers to prepare recommendations for improved communications.

Please relate your answers to calendar year 1970. Give your best estimates only. No detailed analyses are required.

Please answer all questions as completely as possible. Attach extra continuation sheets if necessary. If you have any questions, contact the Management Sciences Staff in Berkeley, California.

The self-addressed envelope should be used to mail the questionnaire by April 5, 1971.

Name (optional) ______________________

Position STAFF / FOREMAN

* Telecommunications is the sending and receiving of messages with artificial aids at a distance.

Form 4

TELECOMMUNICATIONS QUESTIONNAIRE

1. For those activities shown in the table in which you were an active participant, complete columns 3 through 13, using the following guides:

Column (3) The average crew size (including yourself) on that particular activity.

Column (4) Total pay periods or fractions thereof spent on activity by you and your crew during calendar year 1970.

Column (5) Number of radios you had with you on activity ("0" if without radios). State whether equipment portable PL light, PH heavy, mobile M, or other type.

Column (6) State what, if any, other means of telecommuncations you had available on that job (telephone, radio-telephone, etc.).

Column (7) Estimate the percentage of your telecommunications on job transmitted over radio (100%, 90%, 0%, etc.).

Columns (8), (9), and (10)

Enter your best estimate of the usual number of calls per pay period on this activity placed by you and/or your crew members.

Column (8) Administrative: reporting time or equipment use, etc.

Column (9) Project work related: instructions, ordering equipment and/or supplies, etc.

Column (10) Fire related: fire standby, fire weather, fire instructions, fire reporting, etc.

Column (11) How many calls did you and crew receive during same period in activity?

Columns (12) and (13)

Do not complete these columns until after you have finished questions 2, 3, and 4. Rate the value of radios separately for activity accomplishment only (Column 12) and fire standby only (Column 13), even if you did not have the use of a radio on a job, according to the following scale:

	Code
Must have radio on this job:	1
Radio very important on this job:	2
Radio important on this job:	3
Radio convenient:	4
Radio unnecessary	5

Question 1, continued

Activity Group (1)	Activities (2)	Av. Crew Size (3)	Time Spent on Activ. (Pay Period or fract.) (4)	Nbr. & kind of radios on job with you (5)	Other comm. equip. available (6)	Calls transmitted over radio (%) (7)	Approx. number of calls placed Per Pay Period: Admin. Calls (8)	Activ. Calls (9)	Fire Calls (10)	Approx. number of calls rec'd per pay period (11)	Value of radios for Activ. (Use code) (12)	Value of radios for fire standby (Use code) (13)
Activity Group I	Timber Sales Prep.											
	Timber Sales Adm.											
	Timber Surveys											
	Reforestation											
	TSI											
	Range Analysis	2	1/2	1M	0	100	3	0	0	3		5
	Range Reveg.											
	Range Structures											
	Rec. Op. & Mtc. ✓	6	[illegible]	1 M 3 PM	0	100	5	20	20	30	3	3
	Rec. Dev.											
	Adm. of wilderness											
Activity Group II	Law Enforcement (incl. all trespass)											
	Watershed Inv.											
	Watershed Restor.											
	Wildlife Inv.	2	1	1M	0	100	6	0	[illegible]		2	3
	Wildlife C&M											
	Land Uses ✓	1	[illegible]	1M	0	100	10		20	35	3	5
Activity Group III	Fire Pre-supp.	1	1	1M	0	100			50	10	1	2
	Insect & Dis. Con.											
	C&M of Adm. Imp.											
	Roads & Trails Mtc.											
	Const. & Pre-Const. R&T											
	General Admin. ✓	1	2	1M	0	100	20		20		3	3

2a. Select one activity representative of your major effort in 1970 within each activity group in the table on page 2 (activity groups I, II, and III) and show:

Activity in Group I : Rec [illegible]

Activity in Group II : Land [illegible]

Activity in Group III: [illegible]

Average travel time to Activity I: 45 (minutes)

If meaningful, show average travel times for:

Activity II: [illegible] (minutes)

Activity III: 10 (minutes)

Average estimated travel time to nearest means of communications other than your radio when engaged in

Activity I: 35 (minutes)

Activity II: 10 (minutes)

Activity III: [illegible] (minutes)

2b. For each of the activities selected in question 2a, consider the direct savings or losses in time to you and/or your crew members due to the use of radio communications. Estimate the frequency of occurrence for the items listed below which apply to your situation:

	Frequency per pay period		
	Activ. I	Activ. II	Activ. III
Reporting, such as time and attendance, while traveling to or from work rather than making special stops for this purpose.			
Making crew assignment, etc., as above.	5		
Saving travel time by eliminating some trips to or from the project area (this may be related to being able to consult over the radio about an unforeseen or new situation).	25	10	20

	Frequency per pay period		
	Activ. I	Activ. II	Activ. III
Saving time by prearranging for the availability of supplies (delivery of pre-mixed concrete, etc.) so that crews would not be delayed.	15		
Expediting the contractor jobs by keeping in closer touch over the radio.			
Other. (List additional time savings/losses, which occur in your work due to use/lack of radios):			
Safety - Check in two boat crews	20		

2c. Give your estimates of the time saving due to the use of radios for each of the three representative activities noted in question 2a if you have had radio communications available:

Time savings to yourself, due to radio use, per pay period:

Activity I 6 (hours)_______(minutes) per pay period

Activity II 3 (hours)_______(minutes) per pay period

Activity III 3 (hours)_______(minutes) per pay period

Time savings to crew members, due to radio use, per pay period:

Activity I 6 (hours)_______(minutes) per pay period

Activity II No crew (hours)_______(minutes) per pay period

Activity III No crew (hours)_______(minutes) per pay period

2d. Estimate overall time lost, if any, through unnecessary or overly long radio communications:

Activity I ________ (hours) 15 (minutes) per pay period

Activity II ________ (hours) 0 (minutes) per pay period

Activity III ________ (hours) 0 (minutes) per pay period

3a. How often during the last year did you go yourself or send someone with a message to people without a radio? I did so 6 (number) of times. I estimate the total time expended specifically on this effort to be 360 (minutes), worth 25 (dollars). Most often involved were:

[illegible] crews & V/S

3b. How often during the same period of time did you receive in the field a message delivered by someone in person because radio communications were not available? I received 0 messages. I evaluate the total time expended specifically on this effort (i.e., had to make a side trip or special trip) to be ________ (minutes), worth ________ (dollars).

4a. Consider benefits other than direct time savings due to the availability of radios which apply to your routine day to day operations, such as:

Need fewer men to accomplish job;

Avoid idle time in activity by being able to seek new instructions;

Can operate more efficiently during high fire danger periods;

Save on mileage by reducing the number of required trips, etc.

List those benefits/losses, including the examples listed above, arising from the availability/non-availability of radios which are important to your work:

PROVIDE FASTER SERVICE TO PUBLIC

SAVES MILAGE

PROVIDES SAFETY FACTOR FOR BOAT CREWS

ALLOWS STANDBY FIRE CREWS TO DO PRODUCTIVE WORK AT AREAS AWAY FROM THE STATION.

PROVIDES SAFETY & COORDINATION ON PRESCRIBED BURNS

4b. Give your estimates of the total value of the benefits from the availability of radios for the three representative activities selected in question 2a during 1970:

Estimates of benefits from use of radios in 1970:

[illegible] INTANGIBLES HERE (ETC) A PLUGGED TOILET IS NOT COSTLY, EXCEPT TO GOOD WILL.

Activity I 500 (dollars)

Activity II 200 (dollars)

Activity III 200 (dollars)

NOTE: Please return to question 1 to complete columns (12) and (13) of the table on page 2.

5. List the places or people (by position) you call in order of the importance of such calls to you. For each item, give your estimate of the number of calls per week during the busy season.

	Place or Position	No. Calls per Week
(1)	REC & LANDS SO	2
(2)	H & D CREW	10
(3)	DIST RANGER	5
(4)	OTHER SO STAFF	4
(5)		
(6)		
(7)		
(8)		
(9)		
(10)		

6. Did you use radio communications during 1970 in emergency situations involving personal safety (exclude fire if no specific safety hazard existed)?

☒ yes ☐ no

If your answer is yes, how often? 3

How did communications facilities, or the lack of them, contribute to the situation?

RADIOS COORDINATED SEARCH EFFORTS PROVIDING RAPID LOCATION OF LOST PEOPLE & ORDERING EMERGENCY EQUIPMENT

7a. How often did you and/or your crew get dispatched to a fire (including initial attack) while you were in the field during all of 1970? 3. What is your estimate of the time savings due to the availability of radio for all these calls, taking into consideration that the disposition of forces would be different without radios:

2 (hours) ______ (minutes)

7b. How often during 1970 were you unable to relay important fire or other emergency information over the radio because:

(1) You had no radio 6 (number times)

(2) Other end had no radio 6 (number times)

(3) Insufficient area coverage 0 (number times)

What is your estimate of the direct losses due to this inability to communicate? 500 (dollars)

8. Did you suffer delays due to congestion of your radio channel in 1970? If so, how frequently and under what circumstances?

☐ All year

☐ Throughout busy season which extends from ______ to ______

☐ Entire length of incident or day

☐ Good part of day or incident

(continued on next page)

/7 Fire only

/7 Fire and high fire danger periods only

/X/ Few days during year, mostly related to emergency situations

/7 Not at all

/7 Short period only, usually during ____________

____

____

9a. What are the busiest times of day on the radio channel during non-fire periods? from 11:00 to 12:00 and from 16:00 to 17:00.

9b. Which statement describes your actions best when you want to make a call and the line is busy?

You monitor the radio traffic over your channel continuously in order to get on immediately after the channel clears in:

/7 No instance

/X/ A few instances (fewer than one-quarter)

/7 A moderate number of instances (about one-quarter)

/7 About one-half of the instances

/7 About three-quarters of the instances

/7 Most of the instances (about nine-tenths)

/7 Always

9c. When you wish to place a call and find the channel busy, and you don't monitor the channel continuously, your actions are best described by:

/X/ I monitor intermittently for a period of (about) 5 minutes and then stop and try again later (in about ____ minutes). WHEN CONVENIENT

/7 I forget it immediately and try later (in about ____ minutes).

/7 Other (please describe) ____________

____

____

10. Do you find it necessary to monitor the forest (district) net to keep informed about the general situation?

[ ] Yes, I do need to monitor the forest (district) net.

[X] I like to monitor the forest (district) net, but it is not very important that I be able to do so.

[ ] No, I do not need to monitor the forest (district) net.

11. When you fail to establish or complete a radio message, what is the cause most of the time?

[X] Lack of radio coverage (can't get out)

[ ] Radio equipment failure

[ ] Other (specify)______________________________

12. Estimate the number of times in the last 6 months the radios you have used malfunctioned while you attempted to use them.

Fixed :	[ ] None	[ ] 1 time	[ ] 2 times	[X] more than 2 times
Mobile :	[ ] None	[X] 1 time	[ ] 2 times	[ ] more than 2 times
Portable:	[X] None	[ ] 1 time	[ ] 2 times	[ ] more than 2 times

13. Estimate the average length of time it takes to get your radio repaired ___1___ (number days).

Is it high priority equipment? [X] yes [ ] no

14a. How many breakdowns of your radio during each season would you consider unacceptable? What would you consider an unacceptable down time?

Summer: more than ___1___ (breakdowns) and ___8___ (hours downtime)

Fall : more than ___1___ (breakdowns) and ___8___ (hours downtime)

Winter: more than ___NON IMPORTANT___ (breakdowns) and ______ (hours downtime)

Spring: more than ___2___ (breakdowns) and ___16___ (hours downtime)

14b. If your radio is out longer than one day, what are the remedial actions taken:

- [ ] Get lower priority use radio
- [x] Use swing set
- [ ] Go without
- [ ] Other____

15. What percent of your district has radio coverage during the busy season?

- [ ] 30%
- [ ] 50%
- [x] 75%
- [ ] 90%

16. What is the general quality of reception you have in the district area covered?

- [ ] Barely intelligible
- [ ] Intelligible
- [x] Good
- [ ] Excellent

17. If your message quality is only intelligible or barely intelligible, what is the reason?

- /̲7 Voices are strong but distorted and difficult to understand
- /̲7 Voices are weak and noisy
- /̲7 Voices are weak and break in and out

18. The following messages are presently represented in one or more of the various code systems. In the "NEEDED" column, check (✓) those messages you feel definitely need a code assignment because of their importance and consistent use; in the "NOT NEEDED" column check those you feel need not be codified (because, for example, the words themselves are sufficient or clearer than a code). Check only one column for each message. If you have no opinion on a specific message, leave blank.

NEEDED	NOT NEEDED	
✓		Unable to copy; change location
	✓	Finished last assignment
	✓	Arrived at the scene
	✓	Request radio serviceman to be sent to
	✓	Have you dispatched
	✓	Confine message to official business
	✓	Call my home
	✓	Proceed to -
✓		I am now ready to take information
		Standby; am proceeding to better location
✓		Use code
✓		Turn off automatic repeater
✓		Turn on automatic repeater
	✓	Advise if - available for call
✓		What is the correct time
✓		Emergency traffic this station
✓		Routine check-in
		Do you have contact with -
✓		Standby
	✓	Standby, will return your call
	✓	Disregard last message
	✓	Call dispatcher by phone
✓		What is your location
	✓	Return (or I am returning) to station
✓		Weather
✓		Officials or visitors present
✓		Transmitting too rapidly
	✓	Out of service, at home; subject to call
✓		Repeat
✓		In service
✓		Out of service
✓		Verbal repeat

Continued on next page

NEEDED	NOT NEEDED	
✓		O. K. (verbal acknowledgment)
✓		Stop all radio traffic
✓		Receiving well
✓		Receiving poorly
	✓	Brush fire
	✓	Forest fire
	✓	Grass fire
	✓	Structure fire
	✓	Illegal fire or incendiary
	✓	Plane fire
	✓	Vehicle fire
	✓	Traffic conditions, need Highway Patrol
✓		Can handle
	✓	This is legal permit burn
✓		Need FS investigator
✓		Report on conditions
	✓	Check smoke
	✓	Off air at the scene
	✓	Under control
	✓	Air is clear; resume transmitting
✓		All clear; no fires
	✓	What is (or this is) the burning index
✓		Leaving base on patrol flight
✓		Arrived base on patrol flight (returning base)
✓		I have (or do you have) fire traffic
	✓	Take my subsistence order
✓		Emergency fire call
✓		We have no traffic for you
	✓	How is reception
✓		What is the fire condition

19. For messages where the word equivalent could be made almost as brief as a code (e. g., 10-48 vs. "go ahead" instead of "I am ready to take information") which do you prefer:

[ ] Code [X] Word

Why? MANY PART TIME PEOPLE DO NOT KNOW OR REMEMBER THE CODE

20. How many codes can you readily remember?

Less than 10	[ ]	31 - 40	[ ]
11 - 20	[X]	41 - 50	[ ]
21 - 30	[ ]	Over 50	[ ]

21. Should we eliminate the use of codes altogether?

[ ] yes [X] no If no, explain IN MANY CASES THE CODE EXPEDITES TRAFFIC

22. Which codes do you personally use:

	Adm. Traffic	Fire Traffic
Ten code	[X]	[ ]
Four code	[ ]	[X]
Nine code	[ ]	[ ]
Six code	[ ]	[ ]
Other (identify): ________	[ ]	[ ]

23. Would it be advantageous and practicable to combine all necessary codes under one code system?

Explain: NO - EASIER TO REMEMBER IF CODES HAVE DIFFERENT PREFIXES

Exhibit B8

INSTRUCTIONS FOR MAINTENANCE DATA FORM

* Type code (two letter code)

1st Letter	2nd Letter
F = Fixed	t = tube
M = Mobile	k = substantially transistorized
P = Portable	s = solid state

1. List maintenance information is reverse chronological order (i.e. last maintenance performed is listed first, next to last is listed second, etc.)

2. Check appropriate column (P.M = Preventive Maintenance; B.M. = Breakdown Maintenance).

3. Bench time includes only the time required to set up test instruments, diagnose the failure (where applicable), repair the equipment, and take down the test equipment. It should not include travel or time not spent actually working on the specific equipment.

4. Parts costs should be computed exactly whenever possible and estimated in all other cases. (Round off cost to nearest dollar.)

EQUIPMENT CATEGORY DEFINITIONS

1. Fixed Station, tube type, General Electric.
2. Fixed Station, tube type, Motorola.
3. Fixed Station, tube type, Comco
4. Fixed Station, substantially transistorized, Motorola, 0-2 years old.
5. Fixed Station, substantially transistorized, Motorola, 3-5 years old.
6. Fixed Station, substantially transistorized, Motorola, 6-10 years old.
7. Fixed Station, substantially transistorized, General Electric, 0-2 years old.
8. Fixed Station, substantially transistorized, General Electric, 3-5 years old.
9. Fixed Station, substantially transistorized, General Electric, 6-10 years old.
10. Fixed Station, solid state. (Include "lookout"links and repeaters)
11. Mobile, tube type, General Electric.
12. Mobile, tube type, Motorola.
13. Mobile, tube type, Comco.
14. Mobile, substantially transistorized, Motorola, 0-2 years old.
15. Mobile, substantially transistorized, Motorola, 3-5 years old.
16. Mobile, substantially transistorized, Motorola, 6-10 years old.
17. Mobile, substantially transistorized, General Electric, 0-2 years old.
18. Mobile, substantially transistorized, Genreal Elecatric, 3-5 years old.
19. Mobile, substantially transistorized, General Electric, 6-10 years old.
20. Mobile, solid state. (G. E. Porta-Mobiles)
21. Portable, tube or partially transistorized.
22. Portable, solid state, Repco.
23. Portable, solid state, Motorola, 0-2 years old.
24. Portable, solid state, Motorola, 3-5 years old.
25. Portable, solid state, Motorola, 6-10 years old.

Note: Links and Repeaters should be considered as fixed stations.

EQUIPMENT SAMPLE SHEET

Region_____________ Forest_______________

Category	Number of Pieces of Equipment
__________	__________________
__________	__________________
__________	__________________
__________	__________________
__________	__________________
__________	__________________
__________	__________________
__________	__________________
__________	__________________
__________	__________________
__________	__________________
__________	__________________
__________	__________________
__________	__________________
__________	__________________
TOTAL =	__________________

MAINTENANCE DATA FORM

MANUFACTURER________________ TYPE*________________ EQUIPMENT PURCHASE DATE__________

MODEL ________________ P.M. SCHEDULE________ LOCATION: FOREST__________

DISTRICT__________

P

(1) Date of Maintenance			(2) Type of Maintenance		(3) Maintenance [illegible] Time	(4) Costs of Parts Installed
Mo	Day	Yr.	P.M.	B.M.		

*See Type Code in Instructions.

Page___of___Pages

TRAVEL TIME DATA SHEET

Region_______________ Forest_______________ Last FY Battery Expenditures_______________

Total Miles Driven Last Year______________ FOR Charges (Last FY)_______________

Per Mile Charge Last FY_______________

Total Parts Expenditure Last FY___________

Other Travel Expenditures Last FY______________________
(includes costs of helicopters, snowmobiles, etc.)

DISTANCE BETWEEN DISTRICTS *

DISTANCE FROM

DIST.# \ DIST.#										
DISTANCE TO										

*Include Supervisor's Office as a District, and label as S-O.

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
WO

Exhibit B9

REPLY TO: 6170 Safety

May 14, 1971

SUBJECT: The Role of Telecommunications in the Safety of Field Personnel and the General Public

TO: Director of Administrative Management
Attention: Lewis Hawkes

Here are the statistics we discussed on the phone May 11, which may be of help to you in the communications study:

CY 1970 Injury Cases	Estimated Direct Cost per Case (BEC Medical Costs plus Compensation)	Total Direct Costs
2,938 Medical Aid	$18	$ 52,880
701 Disabling Injuries	$760	$532,760
15 Fatalities	$65,000	$975,000
	Grand Total =	$ 1,560,640

The BEC costs per type of case vary from year to year. Also, the Forest Service pays Department of Labor on a fiscal year basis and we keep our injury statistics by calendar year. For FY 1970, the BEC charge was $1,542,760 which does not jibe with the above figure. However, for purposes of the communications study I believe we're close enough.

Injury severity is a matter of chance. The same unsafe act or unsafe condition may lead to a first aid injury one time, and to a disabling injury or death case the next time. Of course, radio and telephone communications have no relationship to severity at the time of injury. However without them, one can expect some first aid cases to become medical aid cases, some medical aid cases to become disabling or lost time cases, etc.

In determining a cost-benefit ratio for telecommunications, indirect costs need to be considered in addition to the $1,500,000 figure above. Indirect costs are generally conservatively placed at four times greater than the direct costs. (See enclosed Technical Release No. 63-R-83 - American Pulpwood Association.)

IMPORTANT !

If better communications could prevent 100 medical aid injuries from becoming disabling injuries, the total savings would be:

\$ \$760 - \$18	=	\$742	Direct cost savings per case
\$742 x 100	=	\$74,200	Total direct cost savings
\$74,200 x 4	=	\$296,800	Total indirect cost savings
		\$371,742	Total savings

Walter E. Schlumpf

WALTER E. SCHLUMPF
Safety Officer

Enclosure

AMERICAN PULPWOOD ASSOCIATION
220 EAST 42nd STREET, NEW YORK 17, N. Y.

Technical Release No. 63-R-83

ACCIDENT COSTS ARE PRODUCTION COSTS

Harvesting - 4.013 December 20, 1963

GENERAL FEATURES: The profit squeeze caused by the narrowing margin between pulpwood price and the cost of production has stimulated a determined search for ways to hold the line on costs. The primary effort is concentrated in fields of mechanization, replacing man-power with machine power. Even in this endeavor, most will agree that there is limited opportunity to cut costs and that we will be satisfied if we can hold costs at present levels by increasing efficiency.

All the while, ignored by most of us, a large area for cutting costs exists. The control of accidents can cut production costs by at least 30 cents a cord on any pulpwood job and could cut much more than that from many jobs. It can be done, it has been done by most other industries, and it needs to be done in our industry.

DEFINITIONS: The meanings of the words "accident" and "injury" are often confused. In safety work the words are often used interchangeably. But, injuries are not accidents. One accident can produce 1, 2, or more injuries. But also, there can be 1 or more accidents without a single injury. Very simply stated:

"Every injury is the result of an accident,
but most accidents produce no injury."

Injuries cost money in terms of medical and compensation costs, lost time, etc., but accidents cost far more in terms of damaged equipment, lost production, down time, and other work stoppages or slow downs.

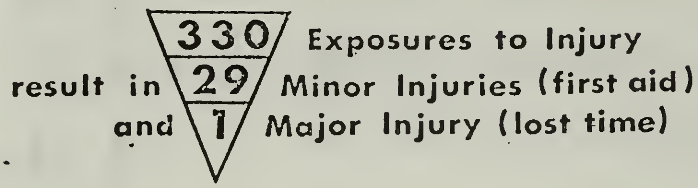
You see why we must be precise in our use of the words "accident" and "injury". If we control accidents, we can realize two areas of cost saving by:

1. Reduction in the cost of injury-producing accidents.
2. Reduction in the cost of no-injury accidents.

The second area for control can save an operator the most money because the potential losses are greater. This is why -

"Accidents are a production problem".

STATISTICAL BACKGROUND: On the basis of extensive studies made of all types of U. S. industry, the safety pioneer H. W. Heinrich, of Travelers Insurance Co., developed the following accident - injury ratio:



A story is often used to illustrate the ratio triangle. Visualize a cable stretched across a doorway a few inches above the floor where many people must pass. As hundreds of people go through the doorway, 330 stands for the number who trip on the cable. Many more came past the cable without tripping. Of the 330 who tripped, 30 sustained some injury. Of the 30 unlucky ones, 29 were injured in a minor way and one had a major injury which was serious enough for him to lose a day or more from work. The 300 who tripped had an accident, tripping, but suffered no injury.

The cable story is simply an example. It does tell us that, in the work situation, 300 no-injury accidents occur for every 30 injury-producing accidents and that no-injury accidents are ten times as numerous as injury producing accidents.

DIRECT INJURY COSTS: Accurate, nationwide statistics on injury in the pulpwood logging business are not available. Nevertheless, a rough estimate can be made based on industry manpower and production surveys and on National Safety Council data.

1.05 cords per man day - Average production rate.[1]
8 hours - Length of average working day.[2]
76.2 lost time injuries per 1,000,000 man hours worked.[3]
$730 - Wage compensation cost per lost time injury.[4]

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(1) From a 1956 pulpwood industry survey of manpower requirements.
(2) Author's estimate.
(3) Injury frequency rate for pulpwood logging - "Work Injuries and Work Injury Rates in Logging Operations, 1955", Bureau of Labor Statistics Report No. 154.
(4) Average of reports from 9 State Labor Departments, 1961, "Accident Facts, 1963 Edition", National Safety Council, Stock No. 021.63.

With the above data we can estimate the average direct cost per cord of lost time injuries in the pulpwood industry:

$$\frac{76.2 \times 730 \times 8}{1,000,000 \times 1.05} = \underline{\$0.42 \text{ per cord}}$$

This 42 cents per cord figure may sound high to you unless you are paying Workmen's Compensation Insurance rates in one of 12 southern states. The average rate for these 12 states is \$10.50 per \$100 of payroll.(5) Ten of the 12 states use upset payroll factors. These ten average out at \$3.88 of payroll per cord.(5) The average W. C. I. payment per cord can be calculated.

$$\frac{\$10.50 \times \$3.88}{\$100.00} = \underline{\$0.41 \text{ per cord}}$$

INDIRECT AND HIDDEN COSTS: Earlier we showed that 29 minor injuries occurred for every major lost time injury. These cost money, too. In addition, all 330 accidents cost money in terms of work interruptions, equipment damage, etc.

Heinrich, in his study, found that the indirect cost of injuries was four times as great as the direct costs, a four to one ratio. Lateiner(6) projected this ratio into the probable cost of no-injury accidents and developed an illustration using an "iceberg" to demonstrate the cost relationship.

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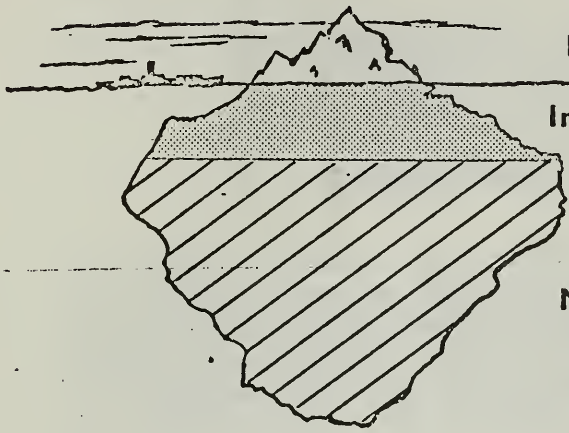
(5) APA Technical Paper 63-P-10, "Recent Developments in Workmen's Compensation", Walter H. Wessels.

(6) "Prevent All Accidents", by Alfred Lateiner, "Industrial Supervisor", National Safety Council publication, January 1959.



In short, for every one dollar of direct injury cost you can expect four dollars of indirect injury costs and twenty dollars of accident costs where injuries did not occur.

In the pulpwood industry, 42 cents per cord direct injury cost indicates an indirect injury cost of $1.68 per cord or a total cost of $2.10 per cord. That's a big piece of the cost of producing pulpwood.

This $2.10 represents only the direct and indirect cost of injuries. If we add on to it the much higher costs of accidents that don't produce injuries the sum becomes almost unbelievable because the numbers are so large. But we can't refute the logic. We can only argue that it may be a little less or a little more.

CONTROL: Everyone knows that you can't stop all injuries because of the obstacles posed by the limitations of our present-day technology (methods), the budgetary limitations in any competitive business, and most of all - human nature. We are dealing with PEOPLE and we can't always get everyone to act 100% safely.

But, it is Al Lateiner's opinion that half of the exposures to accident can be avoided in a reasonable and practical manner. He is backed up in his contention by the facts from dozens of companies who have installed an aggressive

safety program.

Maybe a 50% reduction in the cost of injuries alone in the pulpwood business is too much to expect. You be the judge. A 25% reduction would save 53¢ per cord of the estimated $2.10 total injury cost per cord and would be worth the effort.

<u>The key to control</u> lies in the 330 - 29 - 1 triangle and the cable <u>story.</u> You will recall that these exposures are going on day after day, week after week, and if they are allowed to continue it becomes a mathematical certainty that there will be a major lost-time or serious injury and 29 minor injuries or first aid cases for each 330 exposures. You can't repeal the law of averages. We must stop playing the game of Russian roulette, a game everyone loses eventually.

<u>Accident Costs are Production Costs.</u> The man who has to watch production costs is the only man who can control accident costs. He gets clues when no-injury accidents occur. In fact, according to the ratio triangle he has 300 chances to see an accident for every 30 injuries. The odds are ten to one that the man in charge can see the exposures and take action accordingly.

When workers <u>Act Unsafely</u>, the man in charge of the job should try the following action steps to correct the situation:

1. <u>STOP</u> him, discuss the problem. Toleration implies approval and the exposures begin to accumulate.

2. <u>STUDY</u> the situation. Ask, look, think. Find a better and safer way to do the job.

3. <u>INSTRUCT</u> the worker. Tell, show, try, check. If you find the same man doing the same unsafe thing again, Re-Instruct ! We do not learn with one instruction. This leads to step 4.

4. <u>TRAIN</u> the worker thoroughly to be sure he understands the proper way to do the job. Most will respond to the first 4 steps. If not,

5. <u>MAINTAIN DISCIPLINE</u> by exercising your right to reprimand, suspend, or by some means insist, demand, and require correct practice.

When <u>Unsafe Conditions</u> are found, one of the following action steps can be taken by the man in charge to correct the situation:

1. <u>REMOVE</u> it; if it cannot practically be removed,

2. <u>GUARD</u> it; if you can't remove it and can't guard it, at least,

3. GIVE WARNING in one way or another, such as by posting a signalman, painting it with bright colored paint, posting signs, attaching bells, sirens, flags, lanterns, etc.

The high production cost of accidents can be reduced by the man who is directly in charge of the operation. He is the man with the Opportunity, Authority, and therefore the Responsibility to control accidents.

APA COMMENTS: The theory and in fact the entire approach to accident control expressed in this release, along with most of the phraseology, is taken from Al Lateiner whose method of "Accident Control for Supervision" is known and practiced internationally. The basic triangle and iceberg examples are accepted by safety experts everywhere as being representative of the true facts about accident and injury occurrence and costs. Mr. Lateiner's copyrighted method for accident control has been used successfully in the pulpwood and sawlog industry in Canada for a number of years. The directors of the Quebec and Ontario Safety Associations feel that use of the "Lateiner Method" is largely responsible for their continuing improvement in accident prevention. Interested readers may wish to learn more about this by contacting Mr. Lateiner directly. APA Technical Release 62-R-36 and Technical Paper 63-P-9 describe the Lateiner Method in further detail.

K. S. Rolston
Forest Engineer

Information supplied by:

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REGION: 4 EXHIBIT 10 - SAMPLE BENEFIT TABULATION SHEET

FOREST: B DISTRICT: 6 FOR YEAR: 1970

COMMUNICATION SYSTEM COST: $ ~~11,005~~ 9043 ~~$9,770~~ $11945
(computation from DR Telecomm. questionnaire, pg 2)

DIST. BUDGET: $ 139,433
PFT employees: 9-2

ALL DATA FROM DR & STAFF Telecomm. Quest.

#3a DR & STAFF	#4b DR & STAFF	#3c DR & STAFF		#1(4) DR & STAFF	#9 DR & #6 STAFF		#7a DR & #7a STAFF		
ACTIVITY	EST. RADIO BENEFITS ($)	TIME SAVINGS (HRS) SELF	CREW	NO. DAY PERIODS PER ACTIVITY	NO. EMERGENCY RADIO CALLS: NO. CALLS MADE	POSITION	INITIAL FIRE ATTACK TIME SAVINGS DUE TO RADIO USE (HRS): TIME SAVED	NO.	POSITION
TSA	1500, 300	20,5	20,2	10,5					
L.U.	500, 100	20,1	10,0	15,5	5	DR	509	15	DR
G.A.	100, 500, 100	1,1,2	0,0,0	5,5,2	2	STAFF 1	0	0	STAFF 1
TSP	100	10	10	6	2	" 2	hundreds	55	2
LAW	300, 1000, 500, 400	20,80,4,5	15,0,0,10	2,1,1,3	0	" 3	2	2	" 3
Fire	100 ~~20,000~~ 7375 *	15,20	15,40	3,8	1	" 4	3.5	2	" 4
Rec OP & Mtc	300	8	8	8	0	" 5	6	4	" 5
Range Area	100	1	0	1				8 FIRES TOT.	
Reforest.	20	0	0	6					
R&T	100	5	5	2					
							1.47 hours 4.25 per day		
TOTALS (Non-Fire)	$ 3720	905	548	(used to compute totals of ...)	10	{EMERGENCY CALLS}		{TOT. TIME SAVED HRS.}	

TOTAL, Fire: $7,375 ~~20,000~~ 205 365

#5 DR Questionnaire TOLL CALL SAVINGS: $ 0

DR (5) 4 S+R efforts cut by 90% of lost persons
1 med. aid to injured person

S1 (2) aid ?
S2 (2) ?
S3 (NO)
S4 (1) 1 ambulance 1 hour sooner to woman in labor in mts.
S5 (NO)

#9 DR & #6 Staff emergency radio use benefit:

7375
4850
2525
9420
11945

$ 1592

* reduced to regional average

EXHIBIT B11. Comparison of direct benefits of 1970 model radios to 1960 type models.

a. Portable Radios

Comparisons Based on 1960 P33's and 1970 PT-300, PT-400's	Cost/Year 1960	Cost/Year 1970
Batteries - Because the 1960 radio requires higher standby and receive mode battery drain, we estimate 5 battery changes for 1960 portables versus 2 battery changes for 1970 portables per year. A complete set of batteries costs: 1960 - $13.35; 1970 - $1.20	$66.75	$2.40
	difference - $64.35/yr.	
Maintenance - The average yearly breakdown/maintenance (parts costs, service time, frequency) cost differs for 1960 and 1970 portable radios. (All above are obsolescence costs.)	$15.50	$13.00
	diff. - $2.50/year	

Indirect Benefits of 1970 Portable Radios

The principle beneficial feature of new (1970) portable radios is the reduced size and weight compared to old (1960) portable radios.

Portable Radio - Packset Type

	1970 PT 400	1970 PT 300	1960 P 33
Size (L-W-H)	10"x3 3/4"x10½" 394 in^3	9"x3 3/4"x7 3/4" 260 in^3	11 7/8" x 4 7/16" x 16 5/8" 875 in^3
% decrease	55 %	70 %	
Weight	11 lb. 14 oz.	7 lb. 10 oz.	20 lb. 8 oz.
% decrease	42 %	63 %	
Pwr-Out	10 watts	5 watts	4 watts
% Increase	150 %	25 %	
Wt/Pwr-Out	1.2 lb/watt	1.5 lb/watt	5.1 lb/watt
% decrease	76 %	71 %	
size/pwr-1 ut	39 in^3/watt	52 in^3/watt	218.75 in^3/watt
% decrease	82 %	76 %	

Portable Radio - Personal or Hand-Held Type

	1970	1960
Size	1 13/16" x 3 3/8" x 8 3/16" 50 in^3	3 1/8" x 11¼" x 11 7/8" 417 in^3
% Decrease	88 %	
Weight	1 lb. 15 oz.	10 lb. 1 oz.
% Decrease	81 %	
Pwr-out	1.6 watts	0.8 watts
% Increase	100 %	
Wt/pwr-out	1.21 lbs/watt	12.58 lbs/watt
% Decrease	90.39	
Size/pwr-out	31.25 in^3/watt	521.25 in^3/watt
% Decrease	94.01	

The size of 1970 packset portable radios is reduced by 70 percent from comparable in-power output 1960 radios and the weight by 63 percent. 1970 hand-held or personal portables is reduced 88 percent in size and 81 percent in weight from the closest comparable 1960 portable radios.

The reduction in size and weight of 1970 radios increases the mobility of the user and allows people who previously could not have radio communications, because of the size and weight, to now have communications. The size and weight of 1970 portables allows more of other necessities to be carried on pack trips or other work situations where the size and weight of tools and supplies is limitied.

Another beneficial feature of 1970 portable radios is increased RF power output compared to 1960 portable radios. The increase in power for 1970 packset portable radios compared to 1960 packset portable radios is 25 percent for the smallest and 150 percent for the largest (still with a reduction of 55 percent in size and 42 percent in weight compared to 1960 packset portable radios). The 1970 personal

portable radio has a 100 perce nt increase in power over the comparable 1960 portable
These power increases allow greater range for the field radio and reduces incidences where the user cannot "get in" or where he has to walk or travel to a different spot to "get in".

There are other beneficial features of 1970 portable radios not present in 1960 portable radios. A list would include:

1. Channel capacity increased from two to four.

2. Sturdiness increased by using solid state components, circuit board construction, and impact resistant plastic cases.

3. Expected failures reduced from about 1 every three years to one every 4 years for a decrease in the failure rate of about 12 percent.

Differences in weight implications:

$$7 \text{ lb. } 10 \text{ oz. } (3 \text{ kg}) = 2.8 \text{ C/min}$$

$$20 \text{ lb. } 8 \text{ oz. } (8.07 \text{ kg}) = \underline{3.3 \text{ C/min}}$$

$$0.5 \text{ C/min}$$

Normal continuous endurance pace is walking at 3 mph (level) using 3.8 C/min.

Reduction in energy potential $\frac{0.5 \text{ C/min}}{3.8 \text{ C/min}} = 13.2\%$

Equivalent hour energy loss per year:

385 hrs x 13.2% = 50.6 hrs

50.6 hrs (GS-7/4) x $4.79 = $242

To save $\frac{\$40}{\$4.79/\text{hr}} = 8.35 \text{ hrs} = 13.2\%$

Therefore 100% = 63.3 hrs

b. Direct Dollar Benefits of 1970 MobileRadios Compared to 1960 Mobile Radios

Direct Obsolescence Costs:

	Cost /Year	
Comparisons based on 1960 "TWIN V" and 1970 MOTRAC.	1960	1970
Operating Cost - based on 10-10-80 duty cycle, 7 amp/hr. at 12 volts for 8 hours per day are saved for a reduction in gas consumption of about 38.6 gallons per year. The cost range is $10 to $25 per year.	difference - $17.00	
1960 radios require the vehicle engine to be idling to monitor messages. If an average of 15 minutes idling per day, 22 days per month is assumed, the savings per year are about:	difference - $30.00	
Maintenance - The average yearly maintenance cost differs for 1960 and 1970 portable radios.	$24.00 difference - $12	$12.00
Installation - The size of the 1960 radio requires modification of pickups or trucks or the use of specially built brackets and weather proof cases for installation. 1970 radios can be mounted under the seat of trucks or pickups without modifications or special mounting brackets. Each installation of 1960 equipment costs an estimated $120 more than 1970 equipment. A radio is installed in new vehicles an average of 2½ times over an assumed 10-year life-time for a total of $300 or:		$30/year
		$89/year

Mobile Indirect Obsolescence Costs

The principal beneficial features of 1970 mobile radios is the reduced battery drain when operating on standby or receive and the increased power output of the transmitter compared to 1960 mobile radios.

	1970			1960		
	"Motrac" U53-MHT			"Twin V" T43-GGV		
Power In	Stby	RX	TX	Stby	RX	TX
	5 Watts	30 Watts	300 Watts (60 Watts out)			
TX Power Out	60/90/110 Watts (choice)			25 Watts		

These features are especially important to a field oriented organization like the Forest Service. The low battery drain of 1970 mobile radios allow the crew or forest officer to turn the volume high on their radio and work away from the vehicle (up to 100 yards). This is not possible with 1960 radios without periodic idling of the engine to prevent teh battery from being badly discharged. In periods of high fire danger, when crews must monitor the radio, this feature could save the time of one man. The increased power output (minimum of 140%, maximum of 340%) of 1970 mobile radios to make contact with headquarters and other field units where the 1960 mobile could not. In many cases it makes it unneccessary to drive to places on the forest or district where contact is known to exist. This saves time and vehicle mileage. The higher power output of mobiles

could also mean a simpler radio base station system with fewer base stations needed to obtain adequate coverage.

Other benefits of the 1970 mobile radio include:

1. Less susceptible to ignition noise interference.
2. Channel capacity increased from 2 to 4.
3. Increased sturdiness form solid state components and circuit board construction.
4. Expected failures reduced from 1 every 2 years to 1 every 5 years for a decrease in the failure rate of about 36%.

c. Direct Dollar Benefits of 1970 Fixed Station Radios Compared to 1960 Fixed Station Radios

Comparisons based on . . .	Cost/Year	
	1960	1970
Operating Cost -- based on 10-10-80 duty cycle, power charges of $0.059 per kilowatt-hour, power consumption of 1960 radios would cost more than 1970 radios	$77.74	$42.17
	difference -- $35.57	
Maintenance -- The average yearly maintenance cost differs for 1960 and 1970 fixed station radios. This difference is an obsolescence cost.	$26.00	$6.00
	difference -- $20.00	
	$55.57	

Fixed Station Indirect Obsolescence Costs

The technical specifications and the flexibility of station power output are the principle beneficial features of 1970 fixed stations over 1960 fixed stations.

Better selectivity, lower inherent mixer noise, elimination of RF amplifiers, among less important technical innovations, has greatly reduced the probability of adjacent channel transmitter noie, and intermodulation interference. This increases the clarity, reliability and range of communications. A broader range of environmental specifications allows the equipment to be installed on the average somewhat cheaper since protection against the environment need not be as stringent.

The flexibility of station power output from 30 to 120 Watts allows greater freedom in system design. Fewer stations are needed to cover the same area.

Recently base stations are available using battery power. These stations, using thermoelectric generators to keep the battery charged, offer great possibility in reducing the number of base stations needed to cover an area. These stations are not limited to places where commercial power is available.

Other benefits of the 1970 fixed station include:

1. Channel capacity increased from ___ to ___ .
2. Expected failure reduced from 1 every 2 years to 1 every 5 years for a decrease in failure rate of about 36%.

d. <u>Other General Factors to Consider when Comparing 1970 and 1960 Radios of Any Type</u>

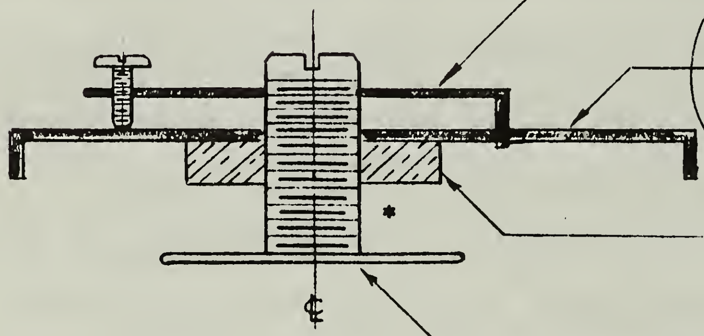
<u>Parts Availability</u> -- 1960 radios are now out of production and therefore many uncommon parts (example: circuit chassis, knobs, relays) must be made on special order when they need replacing. This results in somewhat higher costs and inordinate downtimes. (Page A98.)

e. <u>Other Agencies</u> -- The manufacturers base their lease agreements on an 8 year replacement cycle. High use agencies such as taxi companies replace after 3 years. The concensus of Forest Service Electronics Engineers and all those other agencies interviewed was a 10 year cycle.

BY NM/KK DATE 9-3-70 | SUBJECT P. A. TUNING CAPACITOR ASSEMBLY | SHEET NO. 1 OF

CHKD. BY GVW DATE 9-3-70 | MOTOROLA 406-420 MHZ TRANSMITTERS | JOB NO. 090370

CHASSIS NO. TU263/TTE1010AA/TA184



LOCKING PLATE
MOTOROLA PART NO. 64A821654
NO LONGER AVAILABLE

PA HOUSING COVER
MOTOROLA PART NO. 15B824928
NO LONGER AVAILABLE

BRASS BUSHING
MOTOROLA PART NO. 43A821647

P. A. TUNING CAPACITOR
PLATE AND ADJUSTING SCREW
MOTOROLA PART NO. 51A824942
REPLACED BY 1V844548

NOTE :

* LOCKING SPRING
MOTOROLA PART NO. 41A822468
NO LONGER AVAILABLE

APPLICABLE TO :

ANGELES
CLEVELAND
ELDORADO
INYO
LOS PADRES
MENDOCINO
MODOC
PLUMAS
SAN BERNARDINO
SEQUOIA
SHASTA-TRINITY
SIX RIVERS
TAHOE
PSF RIVERSIDE

NOT TO SCALE

Exhibit B12

TRANSFORMATION OF ANNUAL OBSOLESCENCE COST FROM A FUNCTION OF YEAR AND AGE TO A FUNCTION OF AGE.

a. Establish the year of purchase (N-y+1-a) by subtracting the equipment age from the year of analysis (N-y+1). This shifts the frame of reference to the purchase date.

b. Calculate the number of complete Technological Cycles that have occurred during the equipment lifetime.

c. Calculate the amplitude of any remaining partial cycle. (Often equipment is of an age that is not an integer multiple of the Technological Cycle length (T).

d. Sum the product of the number of complete cycles and the amplitude of AOC'(a) plus the amplitude of the remaining partial cycle to derive the Total Obsolescence Cost, AOC(a).

Let the time of analysis, N-y+1, and the purchase time, N-y+1-a, be expressed as:

$$N-y+1 = jT+w \quad , \qquad j = 0,1,2,\ldots ; \; 0 \leq w<T$$

and

$$N-y+1-a = kT+r, \qquad k = 0,1,2,\ldots ; \; 0 \leq r<T$$

Then, if AOC'(a) denotes the Annual Obsolescence Cost function for one technological cycle,

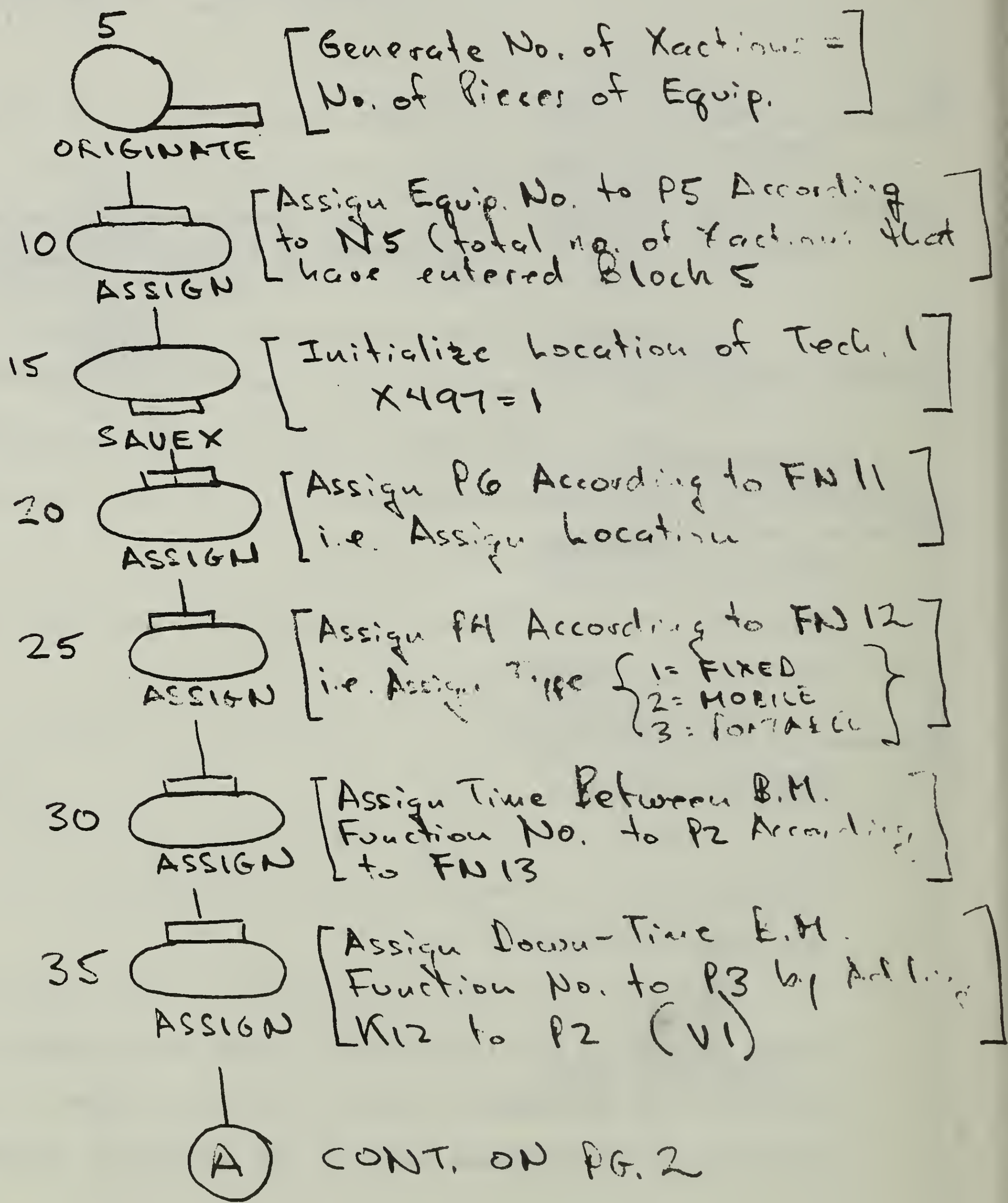
$$AOC(a) = (j-k)\,AOC'(T) + AOC'(w) - AOC'(r), \; (j-k) \geq 0,$$

where AOC(a) is the transformed annual obsolescence cost function for equipment of age a, with the frame of reference shifted to the purchase time of the equipment (Fig. 2).

Exhibit B13

SS FOREST MAINTENANCE SIMULATION - 1 TECH MODEL
REVISION TWO (9/17/71)

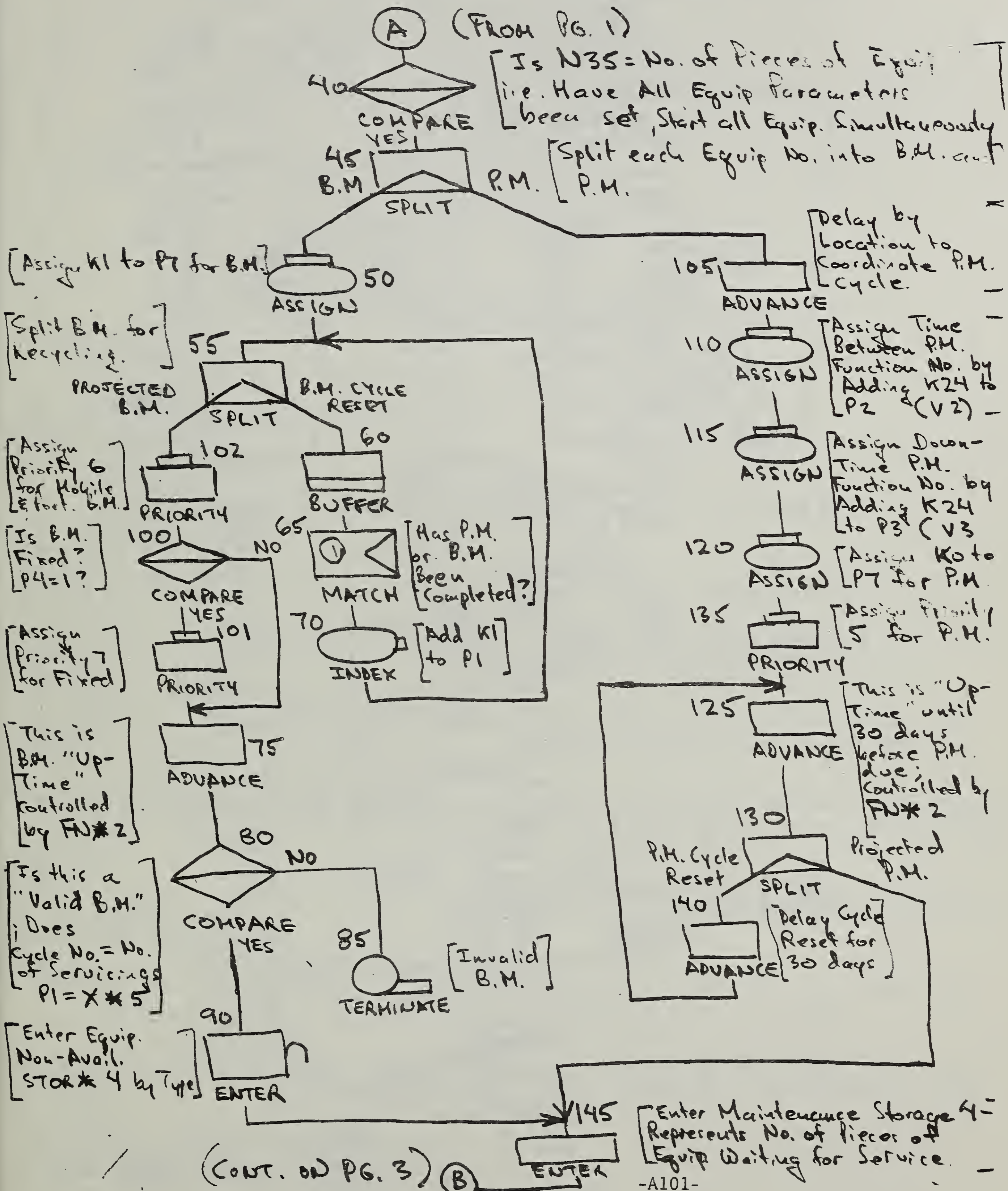
SORTING SECTION



CONT. ON PG. 2

VISION 2 (9/17/71)

P.M. AND B.M. GENERATION SECTION



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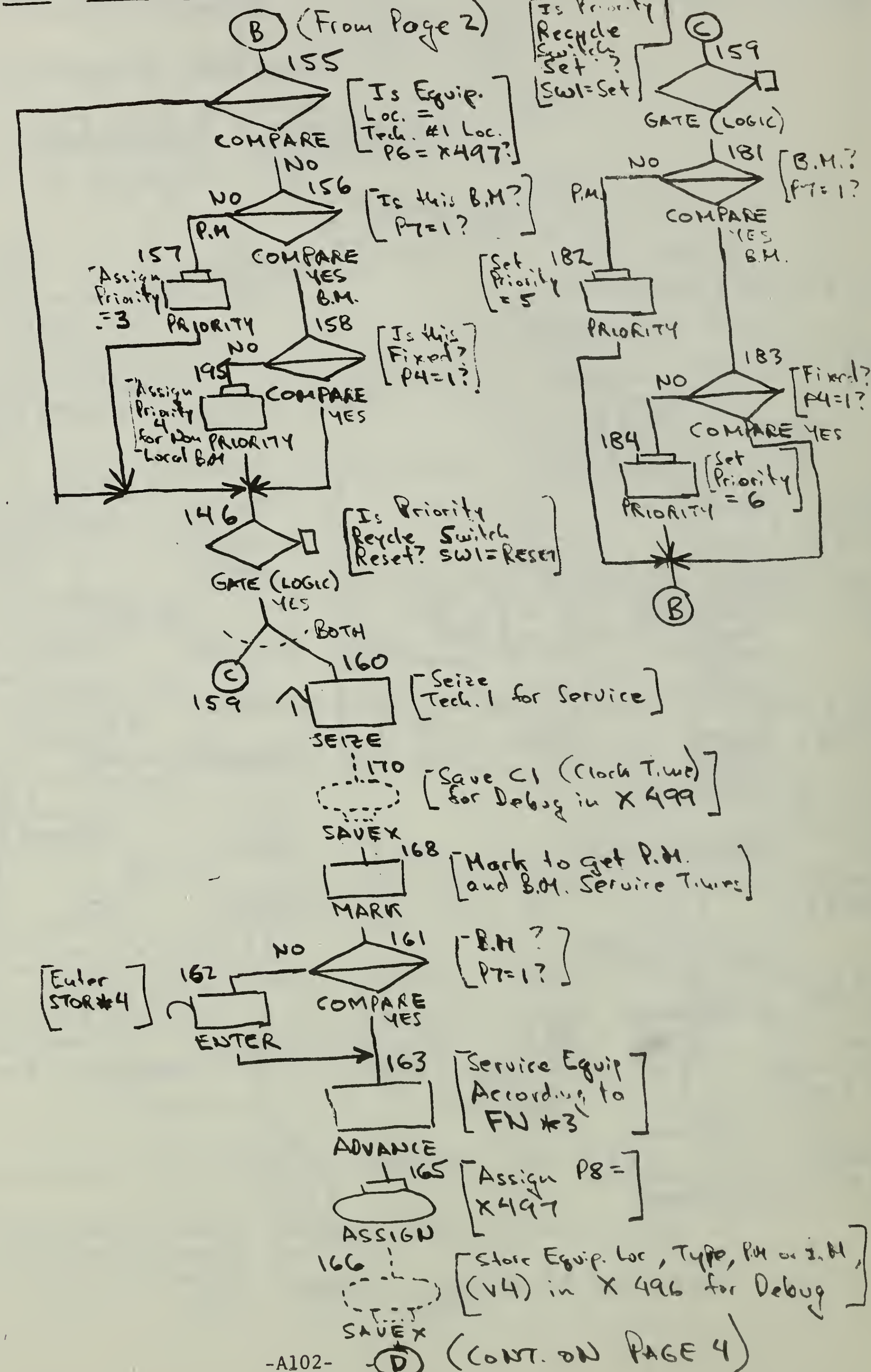
REVISION 2 (9/17/71)

SERVICE ROUTINE



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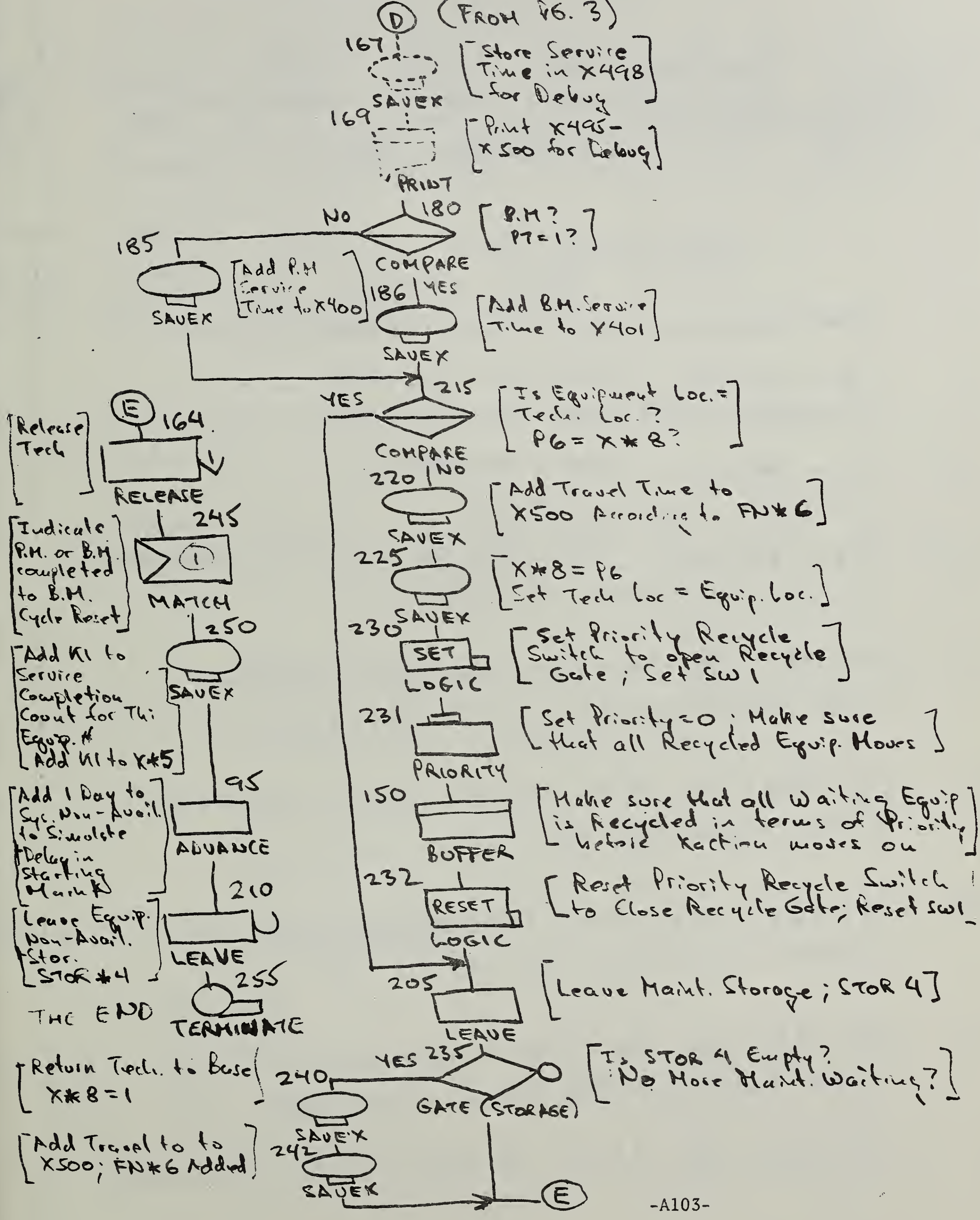
REVISION 2 (9/17/71)

SERVI ROUTINE (CONT.)



(REVISION ONE 8/29/71)

XACT IN PARAMETER FORM T

FOR 1 TECH MODEL

1	2	3	4	5	6	7	8
B.M. CYCLE NUMBER	TIME BETWEEN BREAKDOWN FUNCTION NUMBER	DOWN-TIME DISTRIBUTION FUNCTION NUMBER	TYPE 1= FIXED 2= MOBILE 3= PORTABLE	EQUIP NUMBER (ONE FOR EACH PIECE OF EQUIP)	EQUIP. LOCATION (2-10)	PM = 0 BM = 1	EQUIP TECH STORA LOCA

FUNCTIONS

1-10 {X*8 = ABCISSA; TRAVEL TIME BETWEEN P6 AND X*8 = ORDINA

11 {Nu = ABCISSA; LOCATION = ORDINATE
ASSIGNS EQUIPMENT TO LOCATION

12 {Nu = ABCISSA; TYPE = ORDINATE
ASSIGNS TYPE TO EQUIP.

13 {Nu = ABCISSA; CATEGORY NO. (1-12) = ORDINATE
USED TO ASSIGN P2 AND P3

14-25 {R1 = ABCISSA; TIME BETWEEN B.M. = ORDINATE
ONE FUNCTION FOR EACH CATEGORY

26-37 {R1 = ABCISSA; B.M. SERVICE TIME = ORDINATE
ONE FUNCTION FOR EACH CATEGORY

38-49 {P6 = ABCISSA, (TIME BETWEEN P.M) - (30 DAYS) = ORDINATE
ONE FUNCTION FOR EACH CATEGORY

50-61 {R1 = ABCISSA; P.M. TIME = ORDINATE
ONE FUNCTION FOR EACH CATEGORY

62 {P6 = ABCISSA; DELAY IN P.M. CYCLE = ORDINATE

(REVISION ONE 8/29/71)

SAVEX LOCATIONS

3-19 { B.M. + P.M. SERVICE COUNT FOR EACH EQUIP. # (P5)

1 - PRESENT LOCATION OF TECH.

500 { TOTAL TRAVEL TIME

400 - TOTAL P.M SERVICE TIME

401 - TOTAL B.M. SERVICE TIME

STORAGE LOCATIONS

1-3 { EQUIPMENT NON-AVAILABILITY FOR FIXED, MOBILE AND PORTABLE EQUIP. RESPECTIVELY

4 { MAINTENANCE STORAGE - NO. OF PIECES OF EQUIP WAITING FOR SERVICE.

FACILITIES

1 = 1st TECHNICIAN (HIGHEST PRIORITY)

VARIABLES

1 P2+K2

2 P2+K24

3 P3+K24

```
LOC  NAME          X       Y      Z       SEL   NBA     NBB   MEAN    MOD   REMARKS
```

FOREST MAINTENANCE SIMULATION PROGRAM (1 TECHNICIAN MODEL)

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     J08
*FOREST RADIO MAINTENANCE SIMULATION I
 1   FUNCTION      X*8     C6
2    2       4     2       5      1       6     2       7     2       8     1
 2   FUNCTION      X*8     C6
1    2       4     1       5      1       6     4       7     4       8     2
 4   FUNCTION      X*8     C6
1    2       2     1       5      1       6     4       7     4       8     2
 5   FUNCTION      X*8     C6
1    1       2     1       4      1       6     3       7     3       8     2
 6   FUNCTION      X*8     C6
1    2       2     4       4      4       5     3       7     0       8     1
 7   FUNCTION      X*8     C6
1    2       2     4       4      4       5     3       6     0       8     1
 8   FUNCTION      X*8     C6
1    1       2     2       4      2       5     2       6     1       7     1
 11  FUNCTION      N15     D7
19   1       37    2       52     4       67    5       84    6       100   7
115  8
 12  FUNCTION      N20     D21
3    1       11    2       19     3       23    1       30    2       37    3
38   1       45    2       52     3       54    1       61    2       67    3
70   1       77    2       84     3       87    1       94    2       100   3
102  1       109   2       115    3
 13  FUNCTION      N25     D21
3    14      11    17      19     20      23    14      30    17      37    20
38   14      45    17      52     20      54    14      61    17      67    20
70   14      77    17      84     20      87    14      94    17      100   20
102  14      109   17      115    20
 14  FUNCTION      RN1     C18
0    0       .17   316     .32    631     .44   948     .54   1262    .62   1589
.69  1892    .74   2210    .79    2525    .82   2840    .86   3155    .88   3470
.90  3790    .92   4110    .93    4420    .95   5050    .98   6310    1     8420
 17  FUNCTION      RN1     C18
0    0       .08   316     .14    631     .21   948     .27   1262    .32   1581
.41  2210    .50   2840    .57    3470    .63   4100    .69   4730    .73   5370
.80  6620    .89   9160    .94    11780   .96   12920   .97   14200   1     18000
 20  FUNCTION      RN1     C18
0    0       .05   316     .13    948     .21   1600    .30   2400    .37   3200
.44  4000    .50   4800    .56    5600    .60   6400    .65   7200    .72   8800
.80  11200   .86   13600   .92    17600   .94   19200   .96   22400   1     28800
 26  FUNCTION      RN1     C7
0    0       .19   1       .51    2       .73   3       .87   4       .95   5
1    20
 29  FUNCTION      RN1     C7
0    0       .19   1       .51    2       .73   3       .87   4       .95   5
1    20
 32  FUNCTION      RN1     C7
0    0       .38   1       .74    2       .91   3       .97   4       .99   5
1    20
 38  FUNCTION      P6      C7
1    30000   2     30000   4      30000   5     30000   6     30000   7     30000
8    30000
 41  FUNCTION      P6      C7
1    30000   2     30000   4      30000   5     30000   6     30000   7     30000
8    30000
```

```
 44   FUNCTION     P6     C7
1     30000 2      30000 4      30000 5      30000 6      30000 7      30000
8     30000
 62   FUNCTION     P6     C7
1     0     2      0     4      0     5      0     6      0     7      0
8     0
 1    VARIABLE     P2+K12
 2    VARIABLE     P2+K24
 3    VARIABLE     P3+K24
*PROGRAM STARTS HERE                                         1
*SORTING SECTION
 5    ORIGINATE           115                  10            1
 10   ASSIGN       5      N5                   15
 15   SAVEX        497    K1                   20
 20   ASSIGN       6      FN11                 25
 25   ASSIGN       4      FN12                 30
 30   ASSIGN       2      FN13                 35
 35   ASSIGN       3      V1                   40
*P.M. AND B.M. GENERATION SECTION
 40   COMPARE      N35    E      K115          45
 45   SPLIT                                    50     105
 50   ASSIGN       7      K1                   55
 55   SPLIT                                    60     102
 60   BUFFER                                   65
 65   MATCH        245                         70
 70   INDEX        1      K1                   55
 75   ADVANCE                           BOTH   80     85             FN*2
 80   COMPARE      P1     E      X*5           90
 85   TERMINATE
 90   ENTER        *4                          145
 95   ADVANCE                                  210           8
 100  COMPARE      P4     E      K1            101
 101  PRIORITY     7                           75
 102  PRIORITY     6                    BOTH   100    75
 105  ADVANCE                                  110                   FN62
 110  ASSIGN       2      V2                   115
 115  ASSIGN       3      V3                   120
 120  ASSIGN       7      K0                   135
 125  ADVANCE                                  130                   FN*2
 181  COMPARE      P7     E      K1     BOTH   183    184
 182  PRIORITY     5                    ALL    155    157
 183  COMPARE      P4     E      K1     ALL    155    157
 184  PRIORITY     6                    ALL    155    157
 156  COMPARE      P7     E      K1     BOTH   158    195
 158  COMPARE      P4     E      K1            146
 157  PRIORITY     3                           146
 195  PRIORITY     4                           146
 205  LEAVE        4                    BOTH   235    164
 210  LEAVE        *4                          255
 215  COMPARE      P6     E      X*8           205
 220  SAVEX        500+   FN*6                 225
 130  SPLIT                                    140    145
 135  PRIORITY     5                           125
 140  ADVANCE                                  125           30
 145  ENTER        4                    ALL    155    157
 150  BUFFER                                   232
*PM AND BM SERVICE ROUTINES
 155  COMPARE      P6     E      X497          146
 146  GATE         LR1                  BOTH   159    160
 231  PRIORITY     0                           150
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232   LOGIC       R1                         205
160   SEIZE       1                          168
161   COMPARE     P7     E      K1           163
162   ENTER       *4                         163
163   ADVANCE                                165              FN*3
164   RELEASE     1                          245
165   ASSIGN      8      K497         BOTH   180    185
168   MARK                            BOTH   161    162
180   COMPARE     P7     E      K1           186
185   SAVEX       400+   M1           BOTH   215    220
186   SAVEX       401+   M1           BOTH   215    220
159   GATE        LS1                 BOTH   181    182
225   SAVEX       *8     P6                  230
230   LOGIC       S1                         231
235   GATE        SE4                        240
240   SAVEX       *8     K1                  242
242   SAVEX       500+   FN*6                164
245   MATCH       65                         250
250   SAVEX       *5+    K1                  95
255   TERMINATE
1     CAPACITY    18
2     CAPACITY    50
3     CAPACITY    47
4     CAPACITY    115
      START                     5760

CLOCK TIME  REL          5760              ABS          5760
```

TRANS COUNTS

BLOCK	TRANS,	TOTAL	BLOCK	TRANS,	TOTAL	BLOCK	TRANS,	TOTAL
1	0,	0	2	0,	0	3	0,	0
6	0,	0	7	0,	0	8	0,	0
11	0,	0	12	0,	0	13	0,	0
16	0,	0	17	0,	0	18	0,	0
21	0,	0	22	0,	0	23	0,	0
26	0,	0	27	0,	0	28	0,	0
31	0,	0	32	0,	0	33	0,	0
36	0,	0	37	0,	0	38	0,	0
41	0,	0	42	0,	0	43	0,	0
46	0,	0	47	0,	0	48	0,	0
51	0,	0	52	0,	0	53	0,	0
56	0,	0	57	0,	0	58	0,	0
61	0,	0	62	0,	0	63	0,	0
66	0,	0	67	0,	0	68	0,	0
71	0,	0	72	0,	0	73	0,	0
76	0,	0	77	0,	0	78	0,	0
86	0,	0	87	0,	0	88	0,	0
91	0,	0	92	0,	0	93	0,	0
96	0,	0	97	0,	0	98	0,	0
101	0,	82	102	0,	287	103	0,	0
106	0,	0	107	0,	0	108	0,	0
111	0,	0	112	0,	0	113	0,	0
116	0,	0	117	0,	0	118	0,	0
121	0,	0	122	0,	0	123	0,	0
131	0,	0	132	0,	0	133	0,	0
141	0,	0	142	0,	0	143	0,	0
146	0,	181	147	0,	0	148	0,	0
151	0,	0	152	0,	0	153	0,	0
156	0,	145	157	0,	0	158	0,	56
161	0,	172	162	0,	0	163	0,	172
166	0,	0	167	0,	0	168	0,	172

FOREST MAINTENANCE SIMULATION MODEL

TWO TECHNICIAN MODEL 9/24/71

Exhibit B14

SORTING SECTION

5 ORIGINATE — [Generate No of Xactions = No. of Pieces of Equip.]

10 ASSIGN — [Assign Equip. No to P5 According to N5 (total no. of Xactions that have entered block 5)]

15 SAVEX — [Initialize Location of Tech. 1 X497=1]

20 ASSIGN — [Assign P6 According to FN11 i.e. Assign Location]

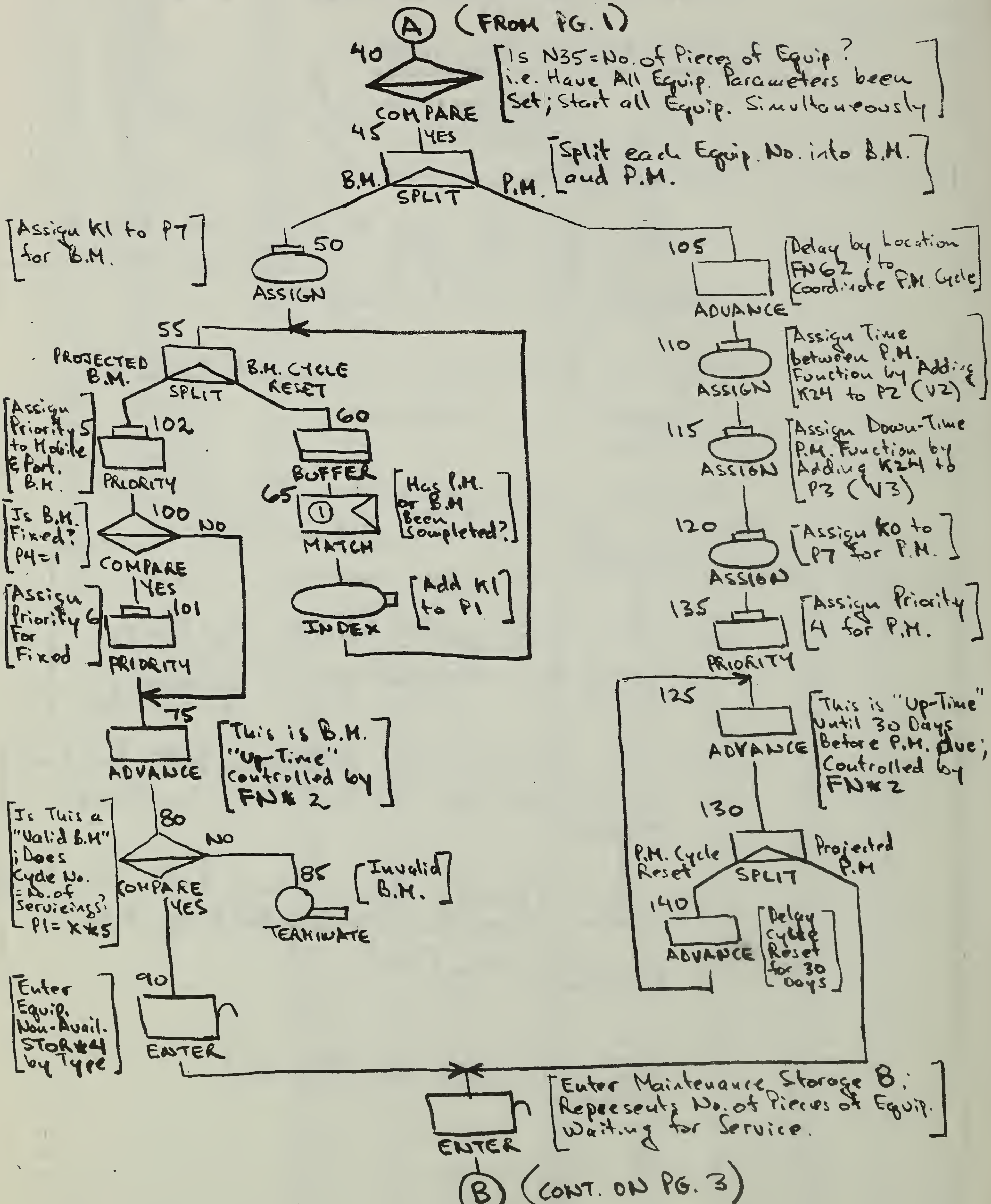
25 ASSIGN — [Assign P4 According to FN12 i.e. Assign Type { 1 = Fixed, 2 = Mobile, 3 = Portable }]

30 ASSIGN — [Assign Time Between B.M. Function No. to P2 According to FN13]

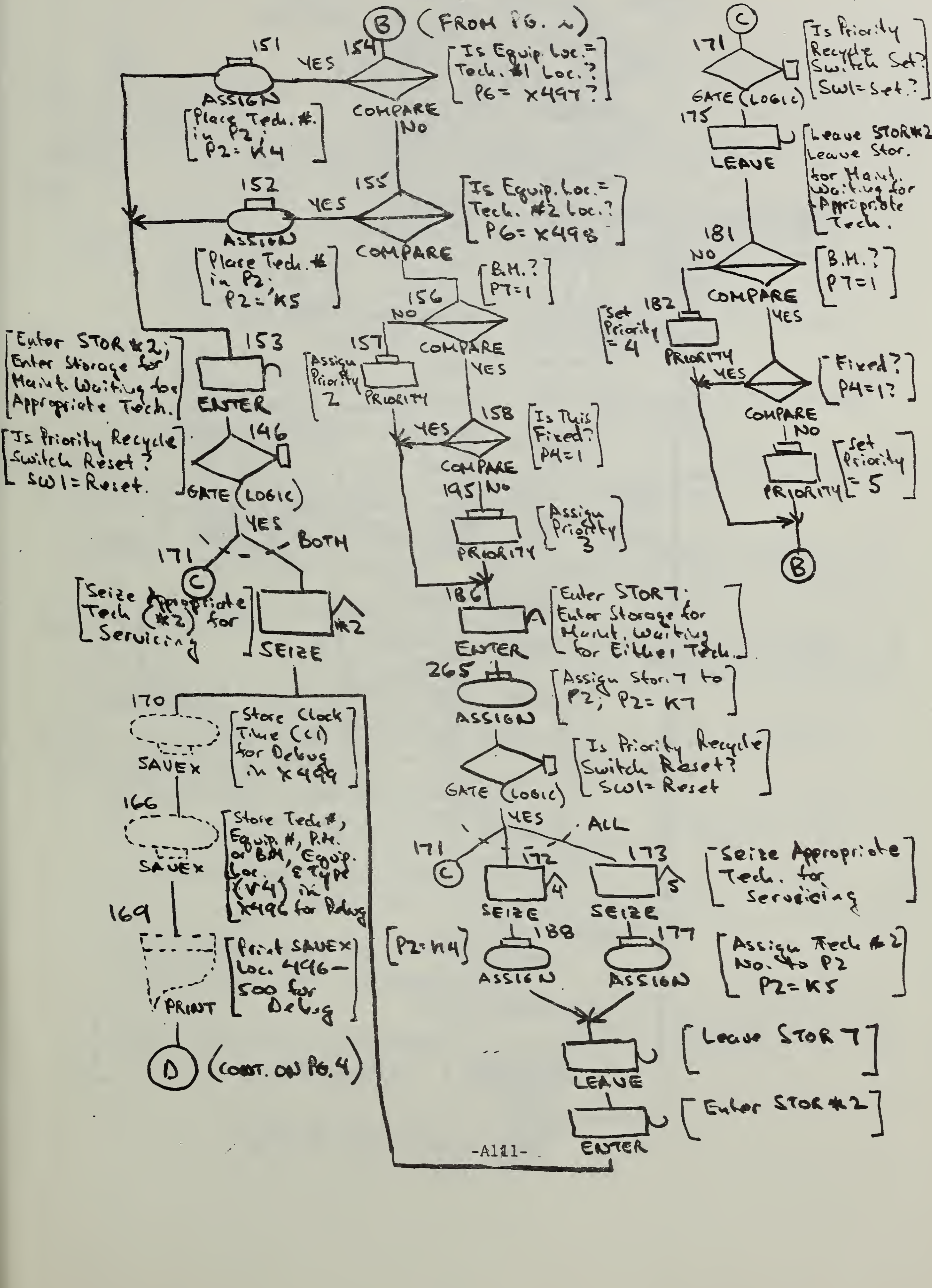
35 ASSIGN — [Assign Down-Time B.M. Function No. to P3 by Adding K12 to P2 (V1)]

A (CONT. ON PG. 2)

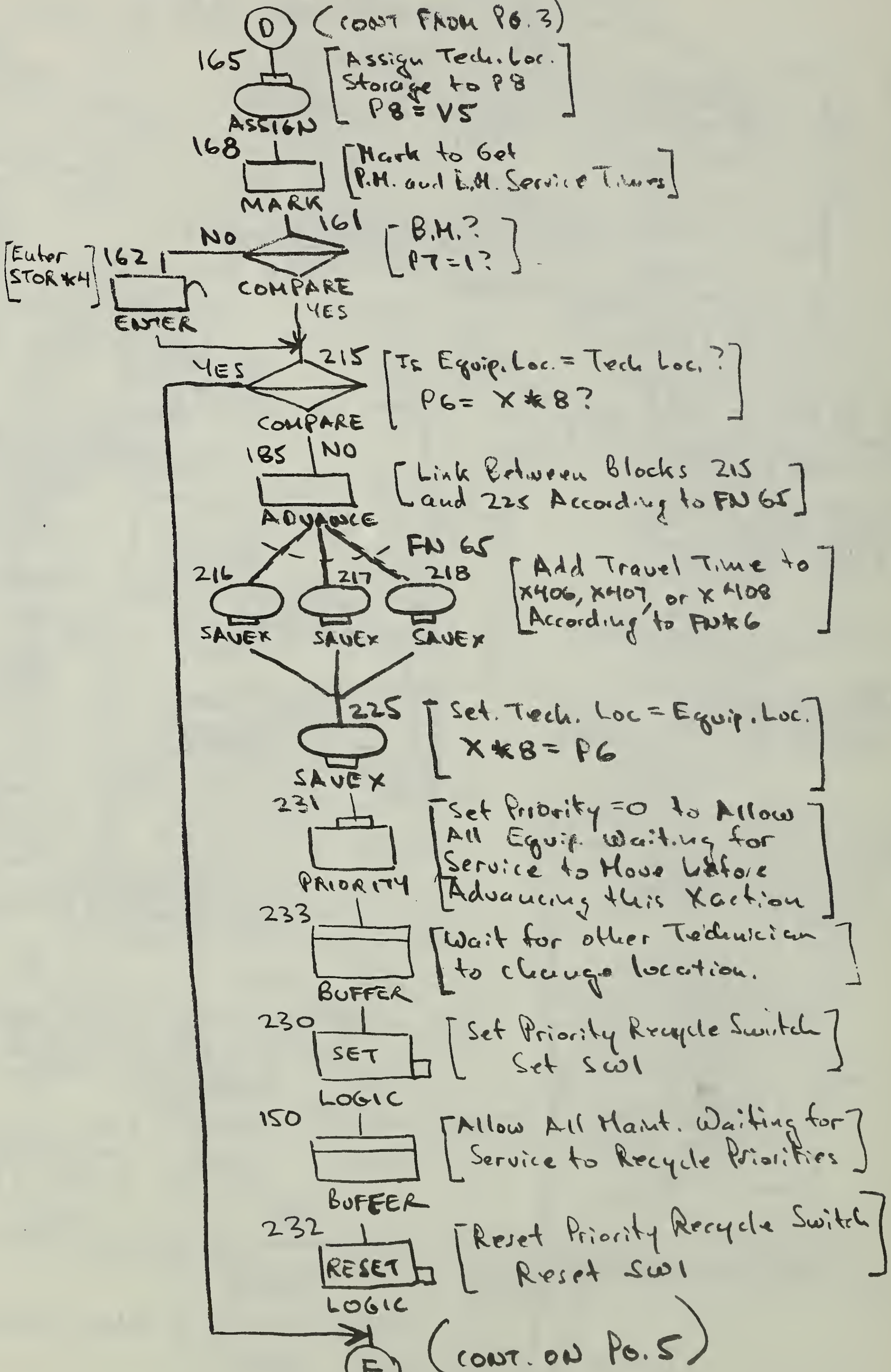
P.M. AND B.M. GENERATION SECTION



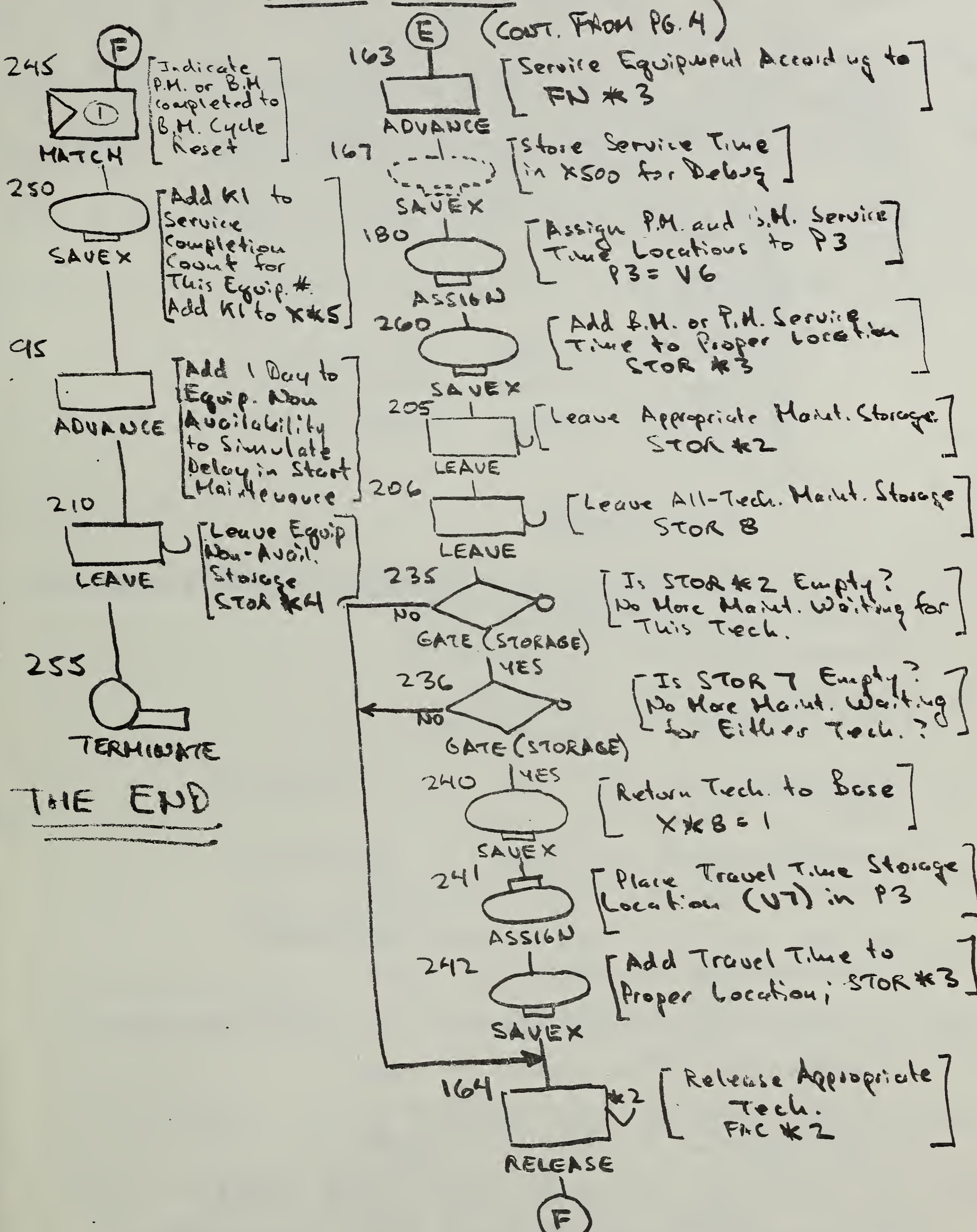
SERVICE ROUTINE



SERVICE ROUTINE (CONT.)



SERVICE ROUTINE (CONT.)



TRANSACTION PARAMETER ASSIGNMENTS
FOR MULTIPLE [illegible] PROGRAM

1	2	3	4	5	6	7	8
B.M CYCLE NO.	TIME BETWEEN MAINT. FUNCTION NO.	DOWN-TIME DIST. FUNCTION NO.	TYPE 1=FIXED 2=MOBILE 3=PORT.	EQUIP. NO. (ONE FOR EACH PIECE OF EQUIP.)	EQUIP. LOCATION (2-10)	P.M.=0 B.M.=1	SERVICING TECH. STORAGE LOCATION
	SERVICING TECH. NO.	P.M. AND B.M. SERVICE TIME STORAGE LOC FOR EACH TECH					
		TRAVEL TIME STORAGE LOCATION FOR EACH TECH.					

FUNCTIONS

1-10 { X*8=ABCISSA; TRAVEL TIME BETWEEN P6 AND X*8=ORDINATE

11 { Nn=ABCISSA; LOCATION=ORDINATE
ASSIGNS EQUIPMENT TO LOCATION

12 { Nn=ABCISSA; TYPE=ORDINATE
ASSIGNS TYPE TO EQUIPMENT

13 { Nn=ABCISSA; CATEGORY NO. (1-12)=ORDINATE
USED TO ASSIGN P2-1 AND P3-1

14-25 { R1=ABCISSA; TIME BETWEEN B.M.=ORDINATE
ONE FUNCTION FOR EACH CATEGORY

26-37 { R1=ABCISSA; B.M. SERVICE TIME=ORDINATE
ONE FUNCTION FOR EACH CATEGORY.

38-49 { P6=ABCISSA; (TIME BETWEEN P.M.)-(30 DAYS)=ORDINATE
ONE FUNCTION FOR EACH CATEGORY

50-61 { R1=ABCISSA; P.M. TIME =ORDINATE
ONE FUNCTION FOR EACH CATEGORY.

62 { P6=ABCISSA; ORDINATE= DELAY IN P.M. CYCLE

65 { P2= ORDINATE; NEXT BLOCK { 216 217 218 = ORDINATE

SAVEX LOCATION

399 {B.M & P.M SERVICE COUNT FOR EACH EQUIP. # (P5)

-499 {PRESENT LOC. OF TECH. #1,2, AND 3 RESPECTIVELY)

-402 {P.M. SERVICE TIMES FOR TECH #1,2, AND 3 RESPECTIVELY

-405 {B.M. SERVICE TIMES FOR TECH #1,2, AND 3 RESPECTIVELY

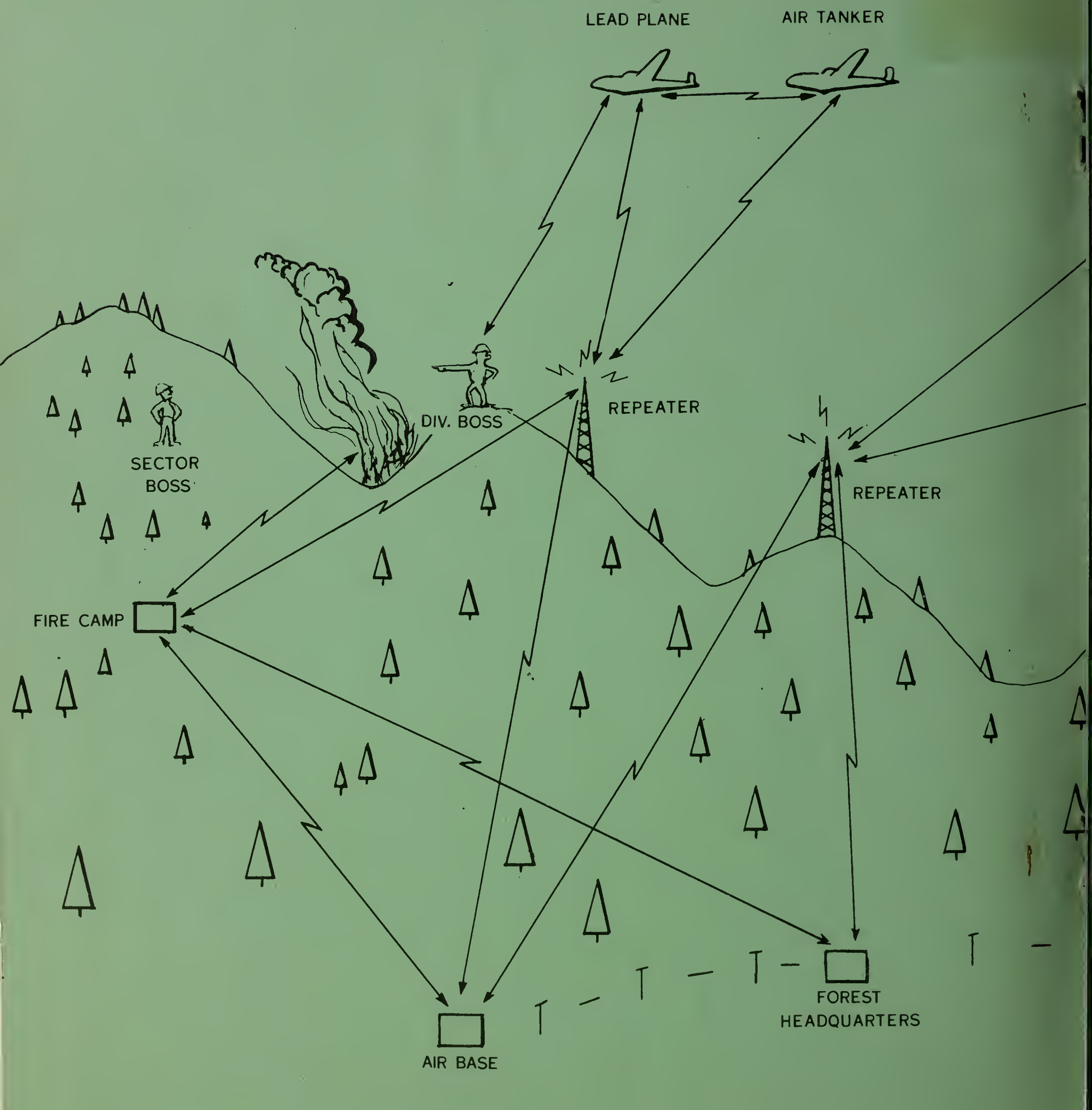
-408 {TOTAL TRAVEL TIMES FOR TECH. #1,2, AND 3 RESPECTIVELY

STORAGE LOCATIONS

1 - FIXED STA EQUIPMENT UNAVAILABILITY
2 - MOBILE " "
3 - PORTABLE " "
4 - MAINTENANCE WAITING FOR TECH. 1
5 - " " " " 2
6 - " " " " 3
7 - " " " ANY TECH.
8 - " " " ALL TECH.

VARIABLES

1 - P2+K12 — USED TO ASSIGN B.M. SERVICE TIME FUNCTIONS
2 - P2+K24 — USED TO ASSIGN P.M TIME BETWEEN MAINT FUNC
3 - P3+K24 - " " " " SERVICE TIME FUNC
5 - P2+K493 - USED TO ASSIGN TECH. LOCATION
6 - P2*K396+P7*K3 - USED TO ASSIGN B.M & P.M. SERVICE TIMES
7 - P2+K402 - USED TO ASSIGN TRAVEL TIMES


LEAD PLANE
AIR TANKER
REPEATER
DIV. BOSS
SECTOR BOSS
REPEATER
FIRE CAMP
FOREST HEADQUARTERS
AIR BASE